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REMARKS ON THE ABERRATION-CONSTANT DETERMINED FROM THE OBSERVATIONS WITH THE UNIVERSAL TRANSIT AT BERLIN, 1884–85.

By F. KÜSTNER.

In *A.J.* 429 a small error has been introduced with respect to the calculation of the aberration-constant from the observations with the Universal Transit at Berlin, 1884–85, it having been assumed, in the employment of the equations taken from *A.N.* 2993, p. 276, involving the instantaneous latitude and the correction, $\varDelta A$, of the aberration-constant, that $\varDelta A$ is the correction to STRUVE's aberration, 20″.445, while it actually indicates the correction to NYRÉN's aberration, 20″.492, as is clearly explained on p. 274, *l.c.* Consequently, by Prof. NEWCOMB's assumptions for $\varDelta\varphi$, which are essentially identical with the values of the latitude-variation given by CHANDLER in 1892, there results,

$$A = 20''.492 + 0''.013 = 20''.505.*$$

If, on the contrary, the values given by CHANDLER in 1894 ($\varDelta\varphi$ II) are introduced, again employing directly the numbers of *A.J.* 429, we have,

$$A = 20''.572 + 0''.047 = 20''.619.$$

This value is, as indeed must necessarily be the case, very nearly identical with the value 20″.611 which Mr. CHANDLER finds by correcting the absolute terms of the individual equations in my memoir (*Berliner Beobachtungs-Ergebnisse*, No. 3, pp. 38–44) by $-2\varDelta\varphi$ II, and correctly applying as he does, according to p. 35, *l.c.*, the resulting correction of the aberration-constant to STRUVE's value, 20″.445. The small difference of 0″.008 may be explained by the fact that, in the use of the three equations of *A.N.* 2993, it is tacitly assumed that the variation of latitude during two or three months is proportional to the time, which is allowable only in a first approximation. The value 20″.611 is thus the more rigorously determined.

While the value 20″.31 cited by Mr. LOEWY under my name (Paris Conference of 1896, *procès-verbaux*, p. 35) is taken from my memoir, it is there (p. 35) determined on the assumption of a constant latitude; thus the correction of STRUVE's aberration $= -0''.132$, so that

$$A = 20''.445 - 0''.132 = 20''.313.$$

I have, however, immediately thereafter (pp. 45, 46), guarded distinctly against the conclusion that this value should be regarded as the result for the aberration-constant from my observations; and in order to prevent any misunderstanding I must recur to the matter in a few words. That I published this result was in general for the reason that I intentionally desired to conduct the reader through the same train of thought that I had myself followed in the treatment of my observations. In this way I was enabled to bring the reader most surely to the positive conviction (although the endeavor was unfortunately unsuccessful, apparently, in the case of Mr. LOEWY) that the latitude actually experiences variations, in the course of the year, of some tenths of seconds. This convincing demonstration was needed at that time to enable us at length to get above the level of mere suspicions, such as had been repeatedly expressed since BESSEL's time. Setting aside the unsuccessful attempts to introduce the Eulerian ten-months period into the calculations, and also the proposal by FERGOLA at Rome in 1883, which had remained fruitless, to investigate a possible secular variation of latitude — these suspicions did not and could not prevent all astronomers and geodesists from treating the latitude as an absolute constant, similarly as we now treat the velocity of the earth's rotation as an absolute constant, although none of us doubt that this also is variable. In the latter case we are still without any numerically certain proof of variability.

The above three strongly discordant values of the aberration-constant found from the Berlin observations of 1884–85, namely,

$A = 20''.313$, latitude assumed constant;

20.505*, latitude assumed variable according to CHANDLER's values of 1892;

20.611, latitude assumed variable according to CHANDLER's values of 1894;

* It may be remarked that this value should properly be 20″.520, since by the strict application of the latitude-corrections in question the quantity $\varDelta A$, on p. 165, becomes $+0''.028$, instead of $+0''.013$ as there given. — ED.

show emphatically how very dependent the aberration is, in this series of observations, upon the latitude-variation. The observed maxima and minima of the effect of aberration accidentally occurred at that epoch coincidently with the greatest elongation of the instantaneous pole for the meridian of Berlin. This lucky circumstance necessarily led to the discovery of the latitude-variation; it was only required to prove that the large discordances of the observations did not have their origin in the instrument, or in the observer, or in the refractions; and thanks to the applied TALCOTT's method this demonstration could be conducted with the necessary sharpness.

On the other hand this strong dependence of the aberration on the latitude-variation is highly unfavorable to the accurate determination of the aberration, and I must therefore adhere to my opinion expressed at that time that this series is not adapted to the determination of the aberration-constant, since it does not contain in itself the means of eliminating the variation of latitude.

Bonn, 1898 *March* 16.

REMARKS ON PROF. BOSS'S THIRD PAPER ON THE PRECESSIONAL MOTION, *A.J.* 430,

BY SIMON NEWCOMB.

Prof. Boss's chapters are arranged so clearly that I shall follow their titles and enumeration.

I. *Personal Equation Dependent on Magnitude.* As what Prof. Boss says on this subject seems substantially identical, in conclusions at least, with what I have set forth in sections II, XVIII and XIX of my paper, I need not say more about it.

II. *Systematic Errors.* The only point here that I need consider is that of the consequences as to relative weights of supposing BRADLEY to have a weight 1, and imagining some combination of star-catalogues at the epoch 1835 to have a weight 6. But there are no star-catalogues at the epoch 1835 having the weight 6 that I have not used to deduce or confirm my results, as I shall presently show. Beyond this Boss's remarks do not annul the important fact that the great mass of material he is alluding to is liable to systematic errors which cannot be discovered except by completely re-reducing the original observations.

III. *Relative Value of Right-Ascensions and Declinations.* I notice nothing to contest in what Prof. Boss says on this subject on p. 171. Page 172 I will return to presently. Interesting and important is what he says on pp. 173, 174 about the smallness of the probable error of the precessional motion derived from declinations. He thinks I have overestimated this error; and the result of his argument is to show that the probable error of the value of n which I derived from declinations,

$$100\,n = 2005''.23 \quad \pm 0''.14 \text{ (epoch 1850)},$$

is markedly less than the value $\pm 0''.14$ here assigned. If Prof. Boss really intended to maintain that my result in question is better than I supposed, I would not stop to argue the point, in view of the fact that it only differs by $0''.12$ from the value, $100\,n = 2005''.11$, which I was led to adopt as definitive by combining the preceding value with that derived from the right-ascensions. Being in doubt on this point I ask leave to show how his argument leads up to it.

On p. 174 he gives a list of thirteen standard authorities among those which he used in forming his normal system, and finds the probable systematic error of $100\,n$ derivable from these authorities to be only $\pm 0''.085$ instead of $\pm 0''.10$ as I had estimated. Now in my recent derivation of a new standard system of declinations I have employed all these authorities (LAUGIER 1853 excepted) and a number of others, notably Pulkowa 1865 and 1885, the Greenwich results up to 1892, Mt. Hamilton 1894–96, and AUWERS'S–BRADLEY, the latter being (so far as the particular correction $\kappa \cos\alpha$ is concerned, which correction is the only one that enters into the present discussion) first reduced to Boss's standard within those zones of declination where it seemed to differ appreciably from that standard. In this way the weight of the result for $\kappa \cos\alpha$ was more than doubled, so that the probable error would be reduced from $\pm 0''.085$ to less than $\pm 0''.06$.

On this system a catalogue of more than 1200 stars was formed, 859 of which are common to AUWERS'S–BRADLEY. The centennial motions of these 859 stars in declination were then compared with those of AUWERS and the means taken for every hour of R.A., omitting *θ Centauri* owing to its discordance, with the following results:

R.A.	$\Delta D_t\delta$ $N-A$	No. of Stars	R.A.	$\Delta D_t\delta$ $N-A$	No. of Stars
h	"		h	"	
0	−0.54	34	12	−0.20	34
1	− .67	43	13	− .39	25
2	− .58	37	14	− .06	36
3	− .68	33	15	− .41	33
4	− .48	35	16	− .68	47
5	− .74	44	17	− .30	40
6	− .57	37	18	− .46	35
7	− .94	33	19	− .74	45
8	− .58	28	20	− .45	45
9	− .72	26	21	− .34	42
10	−0.84	32	22	− .58	39
11	−1.00	28	23	−0.51	37

Giving equal weight to each hour of R.A., and expressing

the difference, $N-A$, in the form $c + \kappa \cos \alpha$, the value of κ comes out $\kappa = -0''.004$.

It thus appears that in this point AUWERS's proper motions may be taken to harmonize absolutely with a standard derived from all existing material up to 1895.

Next consider the accidental error arising from the diversity of proper motions of different stars, and the errors of their individual determinations by AUWERS. On p. 53 of my paper will be found the results for $100\,n$ derived from seven separate zones of declination by two methods of procedure. In the first method the declinations of all those Boss-stars found in AUWERS's–BRADLEY were reduced to 1755, and compared with AUWERS, and, as just stated, systematic corrections to the latter in different zones thus derived. The results are these:

Zone	100 n With red. to Boss	100 n Without red.	Weight
° °	″	″	
−20 to 0	2005.26	2005.26	108
0 " +15	5.59	5.39	96
+15 " 30	5.31	5.27	105
30 " 45	4.66	5.08	71
45 " 60	5.24	5.12	64
60 " 75	5.74	5.34	49
75 " 90	5.17	4.77	30
Mean result	2005.29	2005.23	523

It will be seen that the results are decidedly more harmonious without reduction to the Boss system, a fact which leads me to doubt the reality of the reduction.

If now we determine the probable error from the discordance of the seven independent results, we shall find,

Mean error for weight 1	$\epsilon_1 = \pm 1''.43$
Mean error for weight 523	$\epsilon = \pm 0.062$
Probable error for weight 523	$r = \pm 0.042$

Combining this with the probable systematic error $\pm 0''.06$ we shall have the probable error of $100\,n$, $\pm 0''.073$, and that of the precession, $\pm 0''.18$. But I think an estimate like this smaller than the actual probable error, and am disposed to adhere to my former estimate.

IV. *Meridian Observations of Southern Stars.* Leaving out what Prof. Boss says of my own proceedings and views on this subject, which are in most points entirely misleading, I see nothing under this head which calls for other remark than interest in and appreciation of the projected work of his own which he describes.

V. *Remarks on the Discussion.* As I hope to say nothing more in the *Astronomical Journal* on this subject, I will submit some general remarks.

It seems to me that Prof. Boss's objections to a change of the adopted precession are permanent in their nature, and will be as cogent in 1950, should the STRUVE constants be continued till that date, as they are to-day. There will be no greater "emergency" then than now. There will then be a greater mass of unused material in any discussion of the precessional constant likely to be then made than there is now, for the reason that the total mass will be increased by 50 years of observation, and will be so vast that no one man can handle it up to date. The investigator must therefore select the best on which to base his conclusions, and then there will be no limit to the rhetorical force with which the objector can describe the value of the omitted material, and the magnitude of the mistake made in leaving it out.

Nor will the inclusion of any amount of material make the case of the investigator any better. All astronomical works have imperfections and oversights which the critic can point out and descant upon at any length. A yet worse kind of criticism may be applied to the work by selecting portions of its material to throw doubt on what is left. Mr. HILL's paper in *A.J.* 428, and Boss's on pp. 172–73, afford instances so remarkable that I shall cite them.

In my work on the planetary theories, I completely re-reduced all the meridian-observations of the sun made at Greenwich by MASKELYNE and POND, from about 1765 till 1830 or later, and corrected or re-reduced all made at 13 leading observatories from 1750 to 1892 so far as they were published and available, so as to have an unbroken series of 40,000 observations reduced to one standard. The results are summarized and discussed in Chapter II of my *Elements and Constants*, and the motion of the equinox to which they lead was fully set forth in *A.J.* 359.

Now Mr. HILL corrects my results by selecting the older reductions of some of these same observations, and showing that they lead to results different from mine. Prof. Boss repeats the process on p. 172. I think this worthy of note because that future generation may deem itself fortunate which counts among its numbers an astronomer of more perspicacity than Mr. HILL, or a more accomplished master of the whole subject of star-corrections than Prof. Boss. It is also instructive as showing the possible bad consequences of any attempt to utilize all existing material of any kind.

I may add a word more about the constants of nutation and aberration. Much has been said about the inconvenience that will be caused by the change. The great brunt of this inconvenience has been borne by the Directors of the ephemerides themselves, who have been obliged to correct their tables and formulas. The inconvenience of the investigator who is to correct the adopted values will be much less than theirs, because it will be much easier to allow for the change than it has been to make it. The astronomer who only makes and reduces observations will suffer no inconvenience at all, because it is as easy to use one set of numbers as another in star-reductions.

NOTE ON THE FOREGOING COMMUNICATION,

By LEWIS BOSS.

It seems to me that this discussion between Professor NEWCOMB and myself has reached a point where no good purpose would be served by continuing it; and, therefore, I welcome his intimation that he is ready to have it closed.

I have directed the attention of astronomers pointedly to the question whether it is desirable to recognize the quasi-official determination of astronomical constants by a conference not duly authorized to represent the general body of astronomers. This has obliged me to consider Professor NEWCOMB's work on the precessional motion in the light of the virtual claim it makes (through the Conference) to general assent and adoption. Otherwise I should not have written a word in criticism of that work. Furthermore, I have endeavored to consider only the broader questions involved in the work, neglecting less important defects for lack of time and space.

The ease and apparent candor with which Professor NEWCOMB concedes nearly all the propositions of a technical character which I have advanced, even to the verge of inconsistency with his former views, is more than offset by his manner of dealing with other matters, as illustrated under heads II and IV of the foregoing communication. But if those who feel an interest in this question will carefully compare my various communications with Professor NEWCOMB's original work, and his rejoinders, I shall be quite content to rest the case in that way.

There are, however, three points upon which a few words of further comment appear desirable.

First, what I have said as to the probable accuracy with which $100\,\Delta n$ could be determined is perfectly clear and has referred chiefly to consideration of systematic error of the form $\kappa \cos \alpha$ in the standard declinations, because Professor NEWCOMB laid especial stress upon that point. In every one of my articles, however, I have also pointed out other conditions which seem to me indispensable for the advantageous use of declinations in investigating precessional motion, all of which have been violated in Professor NEWCOMB's work. It is not possible, therefore, that I should have maintained that his result is even better than he thought it. On the contrary, in order to emphasize my distrust of his result and his method I called attention to the discrepancy of $0''.68$ between his value of $100\,\Delta n$ and that of LUDWIG STRUVE, the proper motions in the two cases being virtually identical. Professor NEWCOMB's exhibit under head III appears to me simply to illustrate how deceptive, in the systematic sense, are the results of a discussion of this kind which is founded on only 2000 proper motions, derived from only two series of star-positions, and with four-fifths of the weight in a single hemisphere. The demonstration, in detail, is found in my previous communications on this subject.

Secondly, in his last two articles Professor NEWCOMB has criticised Dr. HILL for the manner in which he attempts to correct the motion of the equinox, N_1; and now Professor NEWCOMB includes me with Dr. HILL in his strictures. He says: "A yet worse kind of criticism may be applied to the work by selecting portions of its material to use in throwing doubt on what is left. Mr. HILL's paper in *A.J.* 428, and BOSS's on pp. 172–73, afford instances so remarkable that I shall cite them." Professor NEWCOMB's arguments are not always stated with sufficient precision to afford the basis of a reply; and what is now the nature of his charge against Dr. HILL and me is not altogether clear, as will appear from the fourth and fifth paragraphs of his head V, in connection with the facts which I proceed to set forth. The casual reader of the fourth paragraph might naturally suppose that this has something to do with his determination of the precessional motion; how little this is the case will presently appear.

Referring now to page 88, of *Elements and Constants*, we shall find that the outcome of Professor NEWCOMB's investigation of the 40,000 sun-observations, of which he speaks, is to correct the centennial motion of his equinox, N_1, by $-0''.34 = \Delta E'$. Including similar corrections derived from observations of *Mercury* and *Venus* he deduces $\Delta E' = +0''.30$. In *A.J.* 336, p. 187, he quotes and apparently indorses this work without change. In *A.J.* 359, p. 188, we find:

	Sun	*Mercury*	*Venus*	Adopted
$\Delta E' =$	$-0''.37$	$+1''.05$	$+0''.20$	$+0''.40$

These values are apparently presented as revisions of those previously cited; but when we come later to the Paris Conference (*Procès-Verbaux*, p. 20) he appears to have returned to the original quantities. The difference, however, is not very material. In response to pressing inquiries, Professor NEWCOMB is reported as saying at the Conference: "Vu la petitesse des corrections pour l'équinoxe du système N_1, il vaudrait peut-être mieux accepter cet équinoxe sans correction." The above is all that I find in regard to Professor NEWCOMB's latest determination of $\Delta E'$, from observations of the sun, up to the publication of "The Precessional Constant"; that is to say, $\Delta E' = -0''.34$. Dr. HILL finds, $\Delta E' = -1''.0$. I prefer, $\Delta E' = -0''.60$; which, in comparison with the value found by Professor NEWCOMB in 1895, and apparently now approved by him, cannot be regarded as seriously discordant. I can scarcely conceive that his complaint has reference to this discordance. It must be remembered, however, that my computa-

tions (*A.J.* 430, pp. 171–2) had reference to the correction, $\Delta E' = +0''.5$, found on page 71 of "The Precessional Constant." "I find," Professor NEWCOMB there says, "that taking the Sun's absolute longitude as given in my new theory, a rough investigation of the Greenwich results during the sixty years, 1835–1895, leads to the approximate value, $\Delta E' = +0''.5$." Strange as it may seem Professor NEWCOMB, in his summing up at this point, does not even mention his former and elaborate investigation, the results of which are exhibited in his *Elements and Constants* (p. 88) and referred to in the foregoing article. Why did he ignore this work of his in the latter half of 1896 and through 1897, to approve it again in 1898? Why does he employ only this "rough investigation" of the modern Greenwich observations, in connection with observations of *Mercury*, to correct the centennial motion of N_1? About three-fifths of these Greenwich observations had been already included in N_1; and this makes Professor NEWCOMB's procedure seem all the more strange. My criticism had direct reference to this singular state of things.

It is true that he finally arrives at the definitive correction, $\Delta E' = +0''.30$; by a coincidence this agrees with his finally adopted correction in the *Elements and Constants;* but he makes no allusion to this coincidence. It appears that this quantity was originally obtained somewhat in the following manner (see also *A.J.* No. 336, p. 187):

Source	$\Delta E'$	Wt.
	$''$	
R.A. of *Sun*	-0.34	2
R.A. of *Mercury*	$+0.79$	3
R.A. of *Venus*	$+0.14$	2
Adopted	$+0.30$	

If the result had appeared in that form, however, objection to the use of observations of *Venus* and *Mercury* for this purpose and with such relative weights would have occurred to nearly every practical astronomer of experience, not excepting members of the Paris Conference (*Procès-Verbaux*, pp. 21, 22). He could then have exhibited his values of $\Delta\psi$ as follows:

Source	$\Delta\psi$
	$''$
R.A.'s of the *Sun*	-0.01
R.A.'s of *Mercury*	$+1.22$
R.A.'s of *Venus*	$+0.51$
Declinations	$+1.12$

Considering the great liability of observed right-ascensions of *Mercury* and *Venus* to anomalous errors of a systematic nature, and, also, the uncertainty which remains in the theories of those planets, an uncertainty which, alone, may well produce an error amounting to a large fraction of a second in the above deductions, I think it would generally be regarded as quite inadvisable and unsafe to retain the second and third of the values in the foregoing table. Excluding these we are confronted with the large discrepancy between the first and last values to which I have frequently alluded. It is this which imperatively demands further examination by independent testimony; especially when LUDWIG STRUVE's investigation would have replaced the above result through declinations by $-0''.60$.

Thirdly, nothing short of the inclusion of every scrap of available evidence bearing on the value of the precessional motion is ever destined to completely satisfy astronomers. They will be restlessly striving for further knowledge until that time. But, meanwhile, Professor NEWCOMB need not fear that the ordinary demand for accuracy in our knowledge of that element, as applied to current use, will go beyond human power to gratify it; or that a pack of ravenous critics is likely to assail every new effort for improvement. Left to themselves, astronomers will, in a natural way, find what best suits their purposes. The demand for accuracy will call out adequate effort to meet it; nor will miracles of endeavor be exacted. For my part, I see no reason why astronomers who choose to do so, should not freely abandon the use of STRUVE's precession now, whenever they may become convinced that they can better themselves and think it worth while. But a very distinct and positive advance in our knowledge is desirable, and a distinct perception that such an advance has been made is required, before concerted action ought to be contemplated.

In conclusion, I wish to remark that what I shall have to present relative to the Southern Star-Catalogues (see *A.J.* 430) need not wear, and is not intended to present, a controversial aspect. Therefore, I may hope that I shall have no further occasion to appear in this discussion in the very distasteful role of critic, — a role which is never pleasant and is rarely profitable. Yet I hope the time and energy employed in this discussion have not been wholly wasted. They will not have been wasted should they stimulate meridian-observers in the smallest degree (and especially the observers at our antipodes) to exercise greater skill, judgement, and diligence in supplying the obvious deficiencies of our knowledge in sidereal astronomy.

CONFIRMATIONS OF VARIABILITY.

BY J. A. PARKHURST.

VARIABLE IN *Lynx*.

$6^h\ 32^m\ 2^s.7$, $+58°\ 2'\ 45''$ (1855).

The variability of this star, which is not in the DM., was announced by ANDERSON in *A.N.* 3467, who found it $10^M.5$, 1897 April 21, and $9^M.5$, Dec. 17. I have measured its position relative to the A.G. Catal. star 58°960, and find it $21^s.6$ following, and 1′ 10″ south, giving the above positions. My observations of its magnitude are as follows:

1898 Jan. 16	10.1	1898 Feb. 5	10.5
17	9.9	15	10.8
18	10.2	23	11.3
20	10.2	Mar. 4	11.4
26	10.3	13	11.4
29	10.0?	23	12.0

This variable has a companion of the 12M or 12M.5, in position angle 155°, distance 12″.6 (result of three night's measures with the 10-inch, kindly communicated by Prof. Barnard. Prof. George C. Comstock's measures on one night, with the 15-inch, are in close accord, angle 154°, distance 13″.2; remark, "difficult").

Variable in *Draco*.

DM. +67°1124 ; 19h 9m 54s , +67° 2′ 4″ (1855).

Anderson (*A.N.* 3463) found this star fainter than 10M.0 in the early autumn of 1897, and 9M.4 on Nov. 26. I have the following observations:

1898 Jan. 4	10.0	1898 Feb. 3	10.7
5	10.0	15	11.1
16	10.4	23	11.6
20	10.6	Mar. 13	11.9
26	10.6	23	12.5

Espin 911.

20h 28m 44s , +54° 28′.5 (1855).

This star was announced as variable by Espin in *A.J.* 426, and further particulars given in *A.N.* 3477. I have the following observations:

1898 Jan. 26	<11.5 invis.	1898 Mar. 6	11.3
27	<12.0 "	13	11.0
Feb. 15	12.5	15	10.9
23	11.7	23	10.8
Mar. 2	11.6	Apr. 1	10.1

I have measured its place with the filar micrometer, relative to the A.G. Catal. stars, DM. +54°2363 and +54°2374, obtaining

R.A. 20h 28m 41s.3 Decl. +54° 28′ 28″ (1855)
29 55.4 37 36 (1900)

There is a 10M star 34s prec., 0′.9 south; an 11M 22s foll., 0′.3 north; and an 11M 39s foll., 0′.6 north, of the variable.

The confirmation here given by Mr. Parkhurst of these variables, the first two discovered by Anderson, the last by Espin, permits the following notation to be assigned:

2376	*S Lyncis*,	(1900)	6h 35m 56s	+58° 0′.5	(1855)	6h 32m 3s	+58° 2′.8
6899	*U Draconis*,		19 9 57	+67 6.9		19 9 54	+67 2.4
7379	*ST Cygni*,		20 29 55	+54 37.6		20 28 44	+54 28.5

ELEMENTS AND EPHEMERIS OF COMET *b* 1898 (PERRINE),

By C. D. PERRINE.

The following system of elements has been obtained from my observations of March 19, 22 and 26.

$$T = 1898 \text{ March } 16^d.79123$$

$$\left.\begin{aligned}\omega &= 46^\circ\ 57'\ 11''.6\\ \Omega &= 262\ 18\ 53.1\\ i &= 72\ 21\ 14.4\end{aligned}\right\}\text{Ecliptic and mean equinox of 1898.0}$$

$$\log q = 0.040024$$

Residuals of the middle place,

$$\text{O}-\text{C},\quad \Delta\lambda\cos\beta = +0''.3\quad,\quad \Delta\beta = -0''.3$$

Constants for the Equator of 1898.0.

$$x = r[9.516976]\ \sin(v + 22^\circ\ 57'\ 23''.6)$$
$$y = r[9.999997]\ \sin(v + 292\ 20\ 32.3)$$
$$z = r[9.975153]\ \sin(v + 22\ 16\ 3.6)$$

Lick Observatory, University of California, 1898 *March* 31.

Ephemeris for Greenwich Mean Midnight.

1898	α	δ	log Δ	Br.
Apr. 7.5	22h 33m 56s	+35° 0′.5	0.2099	0.87
11.5	22 52 37	38 25.2		
15.5	23 12 8	41 32.3	0.2262	0.75
19.5	23 32 24	44 20.3		
23.5	23 53 18	46 48.6	0.2474	0.62
27.5	0 14 38	48 57.1		
May 1.5	0 36 14	50 46.0	0.2714	0.50
5.5	0 57 54	52 16.5		
9.5	1 19 24	53 29.9	0.2963	0.40
13.5	1 40 31	+54 27.8		

Brightness at discovery taken as unity.

ELEMENTS OF COMET *b* 1898 (PERRINE),

By WILLIAM J. HUSSEY.

From Mr. Perrine's observation of March 19, at the time of discovery, and my observations of March 21 and 22, I have computed the following elements of this comet:

$$T = 1898 \text{ March } 19.1079 \text{ Gr. M.T.}$$

$$\left.\begin{aligned}\omega &= 49^\circ\ 31'\ 16''\\ \Omega &= 263\ 19\ 53\\ i &= 72\ 53\ 25\end{aligned}\right\}1898.0$$

$$\log q = 0.04252$$

$$\text{O}-\text{C}: \quad \Delta\lambda\cos\beta = +5'' \quad , \quad \Delta\beta = +3''$$

These elements do not resemble those of any other comet.

The comet has a distinct stellar nucleus, and a tail between one and two degrees in length. According to photographs obtained by Mr. CODDINGTON the tail has branches of the first and second types.

BY C. D. PERRINE.

From my observations of March 19, 21 and 22, I have computed the following elements of this comet.

$$T = 1898 \text{ March } 18.2236 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 48^\circ\,32'\,18'' \\ \Omega &= 264\;54\;34 \\ i &= 72\;42\;16 \end{aligned}\right\} 1898.0$$

$$\log q = 0.04128$$

$$\text{O}-\text{C} \begin{cases} \Delta\lambda\cos\beta = +2'' \\ \Delta\beta \quad\;\; = -11 \end{cases}$$

BY MR. R. T. CRAWFORD AND MR. PALMER.

Telegraphic information from Prof. LEUSCHNER, March 26 and 27, states that the "third observation of Berkeley was slightly erroneously reduced," and gives the following corrected elements in place of those in *A.J.* 431–432, p. 220.

Corrections to the corresponding ephemeris, also telegraphed, are not here repeated, as it has meanwhile expired.

$$T = 1898 \text{ March } 19.06 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 49^\circ\,29' \\ \Omega &= 263\;16 \\ i &= 72\;52 \end{aligned}\right\} 1898.0$$

$$q = 1.1021$$

OBSERVATIONS OF COMET *b* 1898 (PERRINE),

MADE AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,

BY WILLIAM J. HUSSEY.

1898 Mt. Hamilton M.T.		*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Mar. 21	17 10 3	1	15 , 9	−1 3.48	+9 31.3	21 25 59.75	+18 49 16.8	*n*9.647	0.605
22	16 29 13	2	10 , 8	+3 7.32	−0 32.5	21 29 37.50	+19 49 50.9	*n*9.679	0.637
26	16 52 49	3	12 , 8	+1 34.58	−1 15.3	21 45 6.42	+23 58 7.5	*n*9.676	0.578
27	16 0 21	4	*d* 8 , 8	−0 15.03	+5 2.7	21 48 56.90	+24 56 57.6	*n*9.707	0.640
	16 20 34	5	*d*10 , 8	−0 29.22	+1 28.2	21 49 0.33	+24 57 44.9	*n*9.699	0.613
28	16 35 52	6	4	. . . .	+1 20.4	. . . .	+25 59 4.1	. .	0.585
	17 4 46	7	*d*10 , 10	−0 15.40	−2 49.5	21 53 9.73	+26 0 16.4	*n*9.673	0.542
29	16 17 14	8	9 , 8	−1 5.53	−4 7.3	21 57 24.75	+26 54 50.1	*n*9.708	0.606
30	16 9 43	10	12 , 8	−1 31.89	+1 9.9	22 1 11.17	+27 57 40.9	*n*9.715	0.609
31	15 56 43	11	8 , 8	−0 55.76	+2 33.3	22 5 23.72	+28 56 8.3	*n*9.724	0.625

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 27 2.81	+0.42	+18 39 51.4	−5.9	Auwers, Berlin A.G. Catal. 8779
2	21 26 29.77	+0.41	+19 50 29.5	−6.1	" " " " 8776
3	21 43 31.48	+0.36	+23 59 28.4	−5.6	Becker, Berlin A.G. Catal. 8406
4	21 49 11.58	+0.35	+24 52 0.5	−5.6	" " " " 8446
5	21 49 29.20	+0.35	+24 56 22.3	−5.6	" " " " 8447
6	21 51 41.05	+0.35	+25 57 49.3	−5.6	Graham, Cambridge, Eng., A.G. Catal. 13020
7	21 53 24.79	+0.34	+26 3 11.4	−5.5	" " " " " 13050
8	21 58 29.95	+0.33	+26 59 2.7	−5.3	10ᴹ ± connected with * 9
9	21 58 31.64	+0.33	+27 3 56.6	−5.3	Graham, Cambridge, Eng., A.G. Catal. 13137
10	22 2 45.74	+0.32	+27 56 36.2	−5.2	" " " " " 13203
11	22 6 19.17	+0.31	+28 53 40.1	−5.1	" " " " " 13251

The observations of March 28 were made with the 36-inch, and all others with the 12-inch telescope. *d* indicates direct measures. March 21, wind blowing 50 to 60 miles an hour.

Mt. Hamilton, Cal., 1898 *April* 2.

OBSERVATIONS OF COMET *b* 1898 (PERRINE).

1898	*	No. Comp.	☌ − * Δα	☌ − * Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ
With the 12-inch Equatorial, Lick Observatory, by C. D. Perrine.*								
Mt. Hamilton M.T. h m s			m s	′ ″	h m s	° ′ ″		
March 19 16 47 21	1	d10 , 8	−0 10.55	−7 9.6	21 18 36.89	+16 43 23.3	n9.663	0.645
21 16 31 8	2	13 , 8	−1 9.03	+7 49.3	21 25 54.20	+18 47 34.8	n9.678	0.646
22 15 32 32	3	10 , 6	+2 58.74	−2 58.8	21 29 28.92	+19 47 24.5	n9.697	0.695
At Vassar College Observatory, by Mary W. Whitney.								
Greenwich M.T.								
March 25 21 37 18	4	12	+0 7.66	−7 33.4	21 40 37.98	+22 48 2.2	n9.655	0.658
At Carleton College Observatory, by H. C. Wilson.†								
Greenwich M.T.								
March 23.9342	. .	. .	. . .	. . .	21 33 3.6	+20 46 20.	. .	. .

Mean Places for 1897.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 18 47.00	+0.44	+16 50 38.9	−6.0	Auwers, Berlin A.G. Catal. 8726
2	21 27 2.81	+0.42	+18 39 51.4	−5.9	" " " " 8779
3	21 26 29.77	+0.41	+19 50 29.5	−6.2	" " " " 8776
4	21 40 29.81	+0.51	+22 55 44.1	−8.5	Becker, Berlin A.G. Catal. 8377

* *d* indicates that Δα was measured with micrometer. Comet has a bright central condensation in the head, surrounded by a nebulosity about 2′ in diameter. Extending away from the sun is a tail probably a degree long. — March 20, cloudy. — March 21, high wind, telescope vibrating some. Comet distinctly visible to naked eye.

† Received by telegraph from Prof. Payne, through the courtesy of Mr. Ritchie.

ELEMENTS OF COMET 1897 III,

By JAMES HEWINS, Jr.

From the elements of this comet given by Mr. Perrine, an ephemeris was computed for each day from October 16 to November 10. Mr. A. B. Frizell also computed the rectangular coordinates. By comparison with this ephemeris the following normal places were formed for the mean equinox 1897.0, after having applied the corrections for parallax and aberration.

Paris M.T.	α	δ	Obsns.
	° ′ ″	° ′ ″	
Oct. 17.5	52 54 36.0	+67 57 6.8	4
23.5	36 52 20.3	+76 44 34.5	3
29.5	350 17 51.7	+81 40 45.9	4

From these positions the following elements were computed:

$$T = 1897 \text{ Dec. } 8.999475 \text{ Paris M.T.}$$

$$\omega = 66° 14' 2''.1$$
$$\Omega = 32\ 4\ 40.5$$
$$i = 69\ 38\ 35.1$$
$$\log q = 0.1317422$$

For the middle place the residuals are,

$$\text{C}-\text{O}, \quad \cos\beta.\Delta\lambda = +1''.0 \qquad \Delta\beta = -2''.6$$

The coordinates for the equator and mean equinox 1897.0, are

$$x = r[9.9381354] \sin(v + 168° 32' 1''.0)$$
$$y = r[9.6971531] \sin(v + 168\ 8\ 25.6)$$
$$z = r[9.9999981] \sin(v + 78\ 26\ 10.1)$$

Harvard University, 1898 *April* 2.

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A NEW GRAPHICAL METHOD OF DETERMINING THE ELEMENTS OF A DOUBLE-STAR ORBIT.*

BY HENRY NORRIS RUSSELL.

Since the apparent orbit of a double star is the projection of the true orbit on the plane of vision, that diameter of the apparent orbit which passes through the star is the orthogonal projection of the true major axis, and the conjugate diameter is that of the true minor axis. The eccentricity of the true orbit is known from the apparent orbit, and hence the ratio of the true major and minor axes can be found.

Now if we increase the projection of the minor axis in the ratio of the true axis, the ellipse which has as conjugate diameters this increased line and the projection of the major axis will evidently be the projection of the circle circumscribed about the true orbit. This ellipse may be readily constructed. It may be called the auxiliary ellipse. Since it is the projection of a circle lying in the plane of the true orbit, its major axis, being unshortened by projection, is evidently parallel to the line of nodes of the plane of the orbit, and equal in length to a diameter of the circle, that is, to the major axis of the true orbit. The ratio of the axes of the auxiliary ellipse is evidently the cosine of the inclination of the true orbit to the plane of vision. All distances perpendicular to the line of nodes are shortened by projection in this ratio. Therefore if we draw a perpendicular from the apparent position P of the periastron upon the major axis of the auxiliary ellipse at a point Q, and take a point R so that QR is to QP as the minor axis of the auxiliary ellipse is to the major, then R will be the position which the periastron would occupy if the orbit was turned about the major axis of the auxiliary ellipse into the plane of vision. Therefore the angle subtended by QR at the center of the ellipse is the angle between the node and periastron in the true orbit.

The elements of the true orbit are thus completely determined. The necessary constructions can all be made with rule and compass, are reasonably simple, and capable of high accuracy.

The period and periastron passage of the star are found in the usual way by area-measurement.

The ephemeris of the star may also be obtained graphically. Given the period, periastron passage, and eccentricity, the eccentric anomaly of the star in its true orbit at any given time can be determined. Now if in the true orbit we let fall a perpendicular from the small star upon the major axis, the ratio of the distance of the foot of this perpendicular from the center to the semi-axis major is the cosine of the eccentric anomaly of the star. The corresponding relation in the apparent orbit is: If we draw through the apparent position of the star a parallel to the projected minor axis, the ratio of the distance from the center of the apparent ellipse of the intersection of this parallel with the projected major axis, to the projected semi-major axis, is the cosine of the eccentric anomaly.

Hence follows the construction: Describe a circle on the projected major axis as diameter. Lay off on it an arc, equal to the eccentric anomaly, reckoning from the apparent periastron in the direction of the star's motion. From the extremity of this arc draw a perpendicular to the projected major axis, and through the foot of this perpendicular a parallel to the projected minor axis. The intersection of this line with the apparent orbit will be the required place of the star. It is interesting to note that the calculation of the ephemeris by this method does not require a knowledge of the position of the plane of the orbit, nor of the orbit in its plane, but only of the eccentricity, periastron passage and period, which are all obtained directly from the apparent orbit.

* In the use of the projection of the circle circumscribing the true orbit this method is identical with that developed by ZWEIRS, *A.N.* 3336. It should be stated that correspondence with Mr. RUSSELL on this point develops the fact that, since writing the above article, he recognizes and desires it to be understood that, while his own work was done independently, and without the knowledge that he had been anticipated, he makes no claim of priority with regard to the geometrical conception involved. — ED.

The method here described of obtaining the elements differs from THIELE's graphical method in employing the projection of the circumscribing circle of the true orbit, while THIELE makes use of the circle which is the locus of harmonic means of the segments of focal chords of the true ellipse. KLINKERFUES's method involves measurement of the position-angles and lengths of the projected major and minor axes, and then a computation by trigonometrical formulas. It can hardly be called graphical in the geometrical sense of the word. It is, however, perhaps the quickest in practice. The new method is somewhat slower, though more rapid than THIELE's. The new method for the ephemeris is on the other hand considerably more rapid than the usual computation, especially when the whole period is to be covered, as the graphical work is very simple.

As an example of this method, I have computed the orbit of *η Cassiopeae*, using about eighty selected observations, which cover the period from 1780 to the present.

By the use of interpolating curves for angle and distance I obtain the following apparent orbit:

Major axis, 16″.02 Minor axis, 10″.64
Angle of major axis, 57°.0 Angle of periastron, 252°.1
Star from center, 3″.74

whence are derived by the above method the following elements:

P 202.5 yrs. e 0.486 i 43°.9
a 8″.25 ☊ 48°.8 λ 211°.2
T 1908.1 n 1°.777

This orbit is quite similar to those recently published.

The observations from which it is derived have all been taken from the original sources, except those marked in the following table with an asterisk, which are taken from the list in SEE's "*Evolution of the Stellar Systems.*" Since the purpose of the computation is illustrative merely, the column of authorities in the table is omitted, for brevity. The agreement of the observed and computed places is satisfactory.

The recent measures made at the Lick Observatory give a larger distance than results from these elements (5″.1), but about the same angle. Measures made at other places are close to the computed values.

The means of the data of observation used, and the agreement of observed and computed places, are shown in the following table:

Date	θ_o	ρ_o	$\theta_o - \theta_c$	$\rho_o - \rho_c$	Date	θ_o	ρ_o	$\theta_o - \theta_c$	$\rho_o - \rho_c$
	°	″	°	″		°	″	°	″
1780.16	70 (est.)	11.27	+13.1	−0.22	1863.13	121.5	6.96	−1.1	+0.06
1782.45	62.1	. .	+ 3.8	. .	1865.26	125.7	6.73	−0.5	+0.03
1803.11	70.8	. .	+ 0.8	. .	1867.60	130.3	6.49	−0.3	+0.02
1814.10	78.5	9.70	+ 2.1	−1.43	1870.69	136.3	6.15	−0.4	±0.00
1820.16*	81.1	10.68	+ 0.8	−0.10	1873.43	142.0	5.87	−0.2	−0.04
1828.01	86.0	10.37	+ 0.4	+0.11	1876.30	149.0	5.59	−0.5	−0.08
1832.22	88.0	9.76	− 0.7	−0.06	1879.31	157.1	5.36	+0.7	−0.09
1835.26	91.2	9.52	+ 0.1	−0.07	1882.56	165.1	5.16	±0.0	−0.10
1841.16	97.5	9.24	+ 1.2	+0.10	1886.22	175.1	4.98	−0.2	−0.11
1847.40	101.8	8.49	− 0.5	−0.04	1889.55	184.4	4.94	−0.8	−0.04
1849.66	105.0	8.26	+ 0.3	−0.04	1892.25*	193.5	4.93	−0.3	+0.01
1851.84	108.0	8.04	− 0.2	−0.03	1895.60	204.4	4.80	−0.2	±0.00
1855.02	112.1	7.79	+ 1.1	+0.05	1897.27	209.3	4.74	+0.2	±0.00
1857.63	115.2	7.29	+ 0.8	−0.18	1898.16†	212.8	4.73	−0.2	+0.02

† This measure was made with the 9½-inch equatorial of the Working Observatory of Princeton University.

A short ephemeris is added.

	°	″		°	″
1899.0	216.2	4.68	1904.0	235.0	4.37
1900.0	219.6	4.63	1905.0	239.1	4.28
1901.0	223.2	4.58	1906.0	243.4	4.20
1902.0	227.1	4.52	1907.0	247.6	4.10
1903.0	231.0	4.45	1908.0	252.5	3.99

Princeton University, 1898 *March* 19.

SECULAR PERTURBATIONS OF *VENUS* FROM THE ACTION OF *JUPITER*,

By ERIC DOOLITTLE.

The elements employed in the following computation are from Dr. G. W. Hill's *"New Theory of Jupiter and Saturn,"* pp. 19, 192, 554 and 558.

Venus.	*Jupiter.*
$\pi = 129°\ 27'\ 42''.83$	$\pi' = 11°\ 54'\ 31''.67$
$i = 3\ 23\ 35.01$	$i' = 1\ 18\ 42.10$
$\Omega = 75\ 19\ 53.08$	$\Omega' = 98\ 56\ 19.79$
$e = 0.00684311$	$e' = 0.04825511$
$\log a = 9.8593378$	$\log a' = 0.7162374$
$n = 2106641''.357$	$n' = 109256''.626$
$m = \frac{1}{408,134}$	$m' = \frac{1}{1047,879}$

Epoch 1850.0 G.M.T.

The orbit of *Venus* was divided into twelve parts with regard to the eccentric anomaly. It will be noticed that, as in previous cases, the sums of the values of the functions corresponding respectively to the odd and even points of division fail to afford a test of the earlier part of the work, owing to the discordance introduced by ϵ, and the roots, G' and G''. The final sums in this case are, however, in very satisfactory agreement; the greatest difference (which occurs in $W_0 \cos u$), corresponds to a difference of but $0''.000,000,018$ in the value of $\left[\frac{di}{dt}\right]_{00}$

The work has been carried twice through from the beginning, and such test equations as were known have been applied.

The constants of the orbit and the auxiliary functions are as follows:

$I = 2°\ 15'\ 11''.35$	$\log k = p9.9998033$
$II = 247\ 36\ 52.56$	$\log k' = p9.9998610$
$II' = 130\ 2\ 45.43$	$\log c = p8.7995614$
$K = 117\ 32\ 48.56$	$c = 0.063032043$
$K' = 117\ 35\ 25.70$	

E	$\log r$	v	A	ϵ	$\log B$	g	h
0°	9.8563557	0° 0' 0''.00	27.41848845	97° 15' 45''.88	0.5230176	0.68960365	27.007779
30	9.8567564	30 11 47.87	27.28099847	132 59 12.16	0.4349088	0.24993195	27.007266
60	9.8578493	60 20 24.50	27.22724715	176 49 40.25	0.3880569	0.00115264	27.006632
90	9.8593378	90 23 31.50	27.27164617	221 9 29.86	0.4279711	0.19594869	27.006515
120	9.8608213	120 20 20.31	27.40230326	257 38 13.59	0.5146887	0.64351702	27.007039
150	9.8619040	150 11 43.65	27.58420446	287 1 57.24	0.5966511	0.89930104	27.007701
180	9.8622996	180 0 0.00	27.76860046	312 21 41.59	0.6568728	0.70874081	27.007850
210	9.8619040	209 48 16.35	27.90607834	335 36 35.79	0.6930657	0.26150512	27.007330
240	9.8608213	239 39 39.69	27.95980514	357 57 36.25	0.7058197	0.00206064	27.006665
270	9.8593378	269 36 28.50	27.91539376	20 15 35.00	0.6954928	0.18594838	27.006520
300	9.8578493	299 39 35.50	27.78474891	43 20 55.76	0.6616578	0.62528757	27.007025
330	9.8567564	329 48 12.13	27.60287233	68 22 41.53	0.6035861	0.87772776	27.007658
Σ_1	9.1559965	900 0 0.00	165.56119337	1245 23 52.32	3.4501135	2.67036233	162.042990
Σ_2	9.1559964	1080 0 0.00	165.56119353	1065 25 31.58	3.4516756	2.67036294	162.042990

E	l	G	G'	G''	θ	$\log \mathfrak{K}$	$\log \mathfrak{L}'$	$\log \mathfrak{N}$
0°	0.347678	27.0068207	0.4107944	0.06215867	7° 35' 44''.57	0.00574768	0.28065745	0.18470221
30	0.210700	27.0069201	0.2483150	0.03726867	5 53 53.53	0.00346017	0.27761215	0.18127767
60	0.157583	27.0066304	0.1578551	0.00027037	4 23 18.41	0.00191340	0.27555166	0.17896019
90	0.202098	27.0062448	0.2331196	0.03108029	5 10 35.79	0.00320418	0.27727161	0.18089169
120	0.332232	27.0061457	0.3936568	0.06053126	7 26 34.62	0.00551791	0.28035168	0.18435840
150	0.513472	27.0064436	0.5728576	0.05812876	8 46 58.16	0.00769513	0.28324824	0.18761506
180	0.697717	27.0068530	0.7344471	0.03573164	9 42 56.80	0.00942826	0.28555246	0.19020526
210	0.835716	27.0069600	0.8475113	0.01142507	10 16 14.68	0.01054435	0.28703562	0.19187230
240	0.890108	27.0066621	0.8901968	0.00008571	10 27 38.97	0.01094130	0.28756298	0.19246500
270	0.845842	27.0062568	0.8541659	0.00806094	10 17 29.01	0.01058711	0.28709242	0.19193611
300	0.714692	27.0061441	0.7465850	0.03101258	9 45 50.06	0.00952253	0.28567775	0.19034610
330	0.532182	27.0064305	0.5886244	0.05521465	8 52 22.88	0.00785489	0.28346069	0.18785389
Σ_1	3.140010	162.0392563	3.3335352	0.18979023	49 22 3.43	0.04307108	1.69535398	1.12103716
Σ_2	3.140010.	162.0392558	3.3449238	0.20117838	49 47 34.05	0.04334613	1.69572073	1.12144975

E	log N	log P	log Q	log V	J'_1	J_2	J_3	F_2
0	7.429 0890	4.844 8027	6.181 3194	6.180 0737	27.032 601 604	+0.145 14043	−0.979 6507	−4.312 1624
30	7.428 2000	4.841 6643	6.177 4038	6.176 6560	27.002 428 557	+0.101 92507	−1.050 2482	−2.596 0090
60	7.429 7377	4.842 3400	6.177 2232	6.177 2178	26.980 449 138	+0.026 91302	−0.839 0983	−0.176 2960
90	7.433 2723	4.846 6166	6.182 2034	6.181 5797	27.031 356 993	−0.070 55224	−0.402 7785	+2.298 6164
120	7.437 8460	4.853 3278	6.189 7695	6.188 5562	27.065 863 046	−0.159 99410	+0.141 7995	+4.165 5781
150	7.442 2392	4.860 6851	6.197 4531	6.196 2891	27.048 572 013	−0.202 67009	+0.648 7166	+4.921 3381
180	7.445 2930	4.866 7491	6.203 4502	6.202 7348	27.006 174 576	−0.176 74090	+0.982 1448	+4.371 5859
210	7.446 2011	4.869 9179	6.206 4140	6.206 1852	26.976 509 919	−0.093 16228	+1.052 7424	+2.655 4331
240	7.444 7133	4.869 3318	6.205 7060	6.205 7043	26.979 786 076	+0.011 24440	+0.841 5929	+0.235 7201
270	7.441 2095	4.865 1139	6.201 5516	6.201 3902	27.007 935 305	+0.097 74464	+0.405 2732	−2.239 1928
300	7.436 6174	4.858 3731	6.195 0025	6.194 3816	27.036 474 318	+0.146 82513	−0.139 3049	−4.106 1538
330	7.432 1742	4.850 9265	6.187 6739	6.186 5682	27.045 934 111	+0.160 10585	−0.646 2222	−4.864 9146
Σ_1	4.623 2964	9.134 9245	7.152 4707	7.148 6684	161.911 558 528*	−0.006 60902	+0.007 4833	+0.178 2719
Σ_2	4.623 2963	9.134 9243	7.152 6998	7.148 6684	161.911 558 518*	−0.006 60905	+0.007 4833	+0.178 2712

* The term G'' has been removed in forming the sums.

E	F_3	R_0	S_0	W_0	$\frac{1}{a} S^{(n)}$	$\frac{1}{a} \sin E\, R^{(n)}$
0°	+0.064 17143	0.001 343 9836	−0.000 008 192 9943	−0.000 147 85238	−0.000 011 404 782	0.000 000 0000
30	−0.013 79964	0.001 337 8723	−0.000 002 720 2988	−0.000 157 83804	−0.000 003 783 208	+0.000 930 3113
60	−0.004 25156	0.001 343 9282	+0.000 002 821 1779	−0.000 126 22122	+0.000 003 913 643	+0.001 614 5721
90	+0.083 85809	0.001 358 8647	+0.000 005 429 2475	−0.000 060 59607	+0.000 007 505 883	+0.001 878 6178
120	+0.162 87446	0.001 376 5538	+0.000 005 019 4299	+0.000 023 05118	+0.000 006 915 652	+0.001 642 4891
150	+0.153 97825	0.001 391 7093	+0.000 003 882 2446	+0.000 103 05711	+0.000 005 335 546	+0.000 956 3448
180	+0.065 95223	0.001 401 8961	+0.000 003 976 8404	+0.000 157 12801	+0.000 005 460 578	0.000 000 0000
210	−0.013 57095	0.001 406 6592	+0.000 004 704 2587	+0.000 169 14113	+0.000 006 465 278	−0.000 966 6180
240	−0.005 63629	0.001 405 3074	+0.000 003 550 4098	+0.000 135 10528	+0.000 004 891 671	−0.001 676 7973
270	+0.081 23098	0.001 396 4225	−0.000 000 872 5072	+0.000 065 03287	−0.000 001 206 233	−0.001 930 5409
300	+0.159 70886	0.001 380 0829	−0.000 006 664 1223	−0.000 020 64190	−0.000 009 244 718	−0.001 658 0071
330	+0.151 12247	0.001 360 2244	−0.000 009 912 2256	−0.000 098 22805	−0.000 013 785 254	−0.000 945 8544
Σ_1	+0.442 81913	0.008 251 7519*	+0.000 000 510 7414	+0.000 020 56897	+0.000 000 532 044	−0.000 077 7432
Σ_2	+0.442 81920	0.008 251 7523*	+0.000 000 510 7192	+0.000 020 56895	+0.000 000 532 012	−0.000 077 7394

* The corresponding logarithms compare as follows: 2.829 9556 2.829 9557.

E	$+R_0 \sin v$ $+S_0 (\cos v + \cos E)$	$-R_0 \cos v$ $+ S_0 \left(\frac{r}{a} \sec^2 \varphi + 1 \right) \sin v$	$W_0 \cos u$	$W_0 \sin u$	$-2 \frac{r}{a} R_0$
0°	−0.000 016 3860	−0.001 343 9836	−0.000 086 632 804	−0.000 119 81268	−0.002 669 5736
30	+0.000 668 2014	−0.001 159 0573	−0.000 015 602 101	−0.000 157 06504	−0.002 659 8877
60	+0.001 170 6512	−0.000 660 1482	+0.000 052 284 193	−0.000 114 88325	−0.002 678 6592
90	+0.001 358 7959	+0.000 020 1574	+0.000 049 346 057	−0.000 035 16889	−0.002 717 7294
120	+0.001 182 9926	+0.000 703 9968	−0.000 022 943 878	+0.000 002 22159	−0.002 762 5280
150	+0.000 685 0081	+0.001 211 4930	−0.000 093 907 380	−0.000 042 45200	−0.002 799 9142
180	−0.000 007 9537	+0.001 401 8961	−0.000 092 067 787	−0.000 127 32924	−0.002 822 9786
210	−0.000 707 3256	+0.001 215 9042	−0.000 017 870 798	−0.000 168 19438	−0.002 829 9915
240	−0.001 216 4221	+0.000 703 7025	+0.000 054 502 775	−0.000 123 62395	−0.002 820 2318
270	−0.001 396 3839	+0.000 011 3009	+0.000 052 437 627	−0.000 038 46518	−0.002 792 8449
300	−0.001 205 8917	−0.000 671 3715	−0.000 020 520 787	+0.000 002 23277	−0.002 750 7212
330	−0.000 701 3026	−0.001 165 7067	−0.000 089 781 837	−0.000 039 84932	−0.002 704 3278
Σ_1	−0.000 093 0097	+0.000 134 0921	−0.000 115 378 288	−0.000 481 19476	−0.016 504 6924
Σ_2	−0.000 093 0067	+0.000 134 0915	−0.000 115 378 432	−0.000 481 19481	−0.016 504 6855

The equation,

$$\sin q \cdot \tfrac{1}{2} A_1^{(s)} + \cos q \cdot B_0^{(c)} = 0$$

is found to give the residual $+0.000\,000\,000\,002\,8$.

If m' is left indefinite, the resulting values of the differential coefficients are the following:

		log coeff.
$\left[\dfrac{de}{dt}\right]_{00} =$	$-32''.654970\ m'$	$n1.513\,9493$
$\left[\dfrac{d\pi}{dt}\right]_{00} =$	$+6874.8117\ m'$	$p3.837\,2608$
$\left[\dfrac{d\chi}{dt}\right]_{00} =$	$+6879.8159\ m'$	$p3.837\,5768$
$\left[\dfrac{di}{dt}\right]_{00} =$	$-40.510972\ m'$	$n1.607\,5727$
$\left[\dfrac{d\Omega}{dt}\right]_{00} =$	$-2854.6599\ m'$	$n3.455\,5544$
$\left[\dfrac{dL}{dt}\right]_{00} =$	$-5799.7390\ m'$	$n3.763\,4084$

If we adopt the mass of *Jupiter* given above:

$$(m' = 1 \div 1047.879),$$

the following values finally result:

$$\left[\frac{de}{dt}\right]_{00} = -0''.0311\,62921 \qquad \left[\frac{di}{dt}\right]_{00} = -0''.0386\,59\,982$$

$$\left[\frac{d\pi}{dt}\right]_{00} = +6.560\,6924 \qquad \left[\frac{d\Omega}{dt}\right]_{00} = -2.724\,2270$$

$$\left[\frac{d\chi}{dt}\right]_{00} = +6.565\,4682 \qquad \left[\frac{dL}{dt}\right]_{00} = -5.534\,7410$$

The values obtained by LeVerrier are stated in the *Annales de l'Observatoire de Paris*, Tome II, chapter 7, and Tome VI, page 6. Those of Newcomb are found on pages 336 and 376 of his "*Secular Variations of the Four Inner Planets.*" If all results are reduced to the above value of m', the three series of values compare as follows:

	Results of LeVerrier	Results of Newcomb	Method of Gauss
$\left[\dfrac{de}{dt}\right]_{00} =$	$-0''.03117$	$-0''.03117$	$-0''.0311629$
$e\left[\dfrac{d\pi}{dt}\right]_{00} =$	$+0.04482$	$+0.04491$	$+0.0448955$
$\left[\dfrac{di}{dt}\right]_{00} =$	-0.03865	-0.03865	-0.0386600
$\sin i\left[\dfrac{d\Omega}{dt}\right]_{00} =$	-0.16114	-0.16122	-0.1612345
$\left[\dfrac{dL}{dt}\right]_{00} =$	-5.535	–	-5.5347410

The Flower Observatory, 1898 *April* 5.

A FORM OF PERSONAL EQUATION,

By TRUMAN HENRY SAFFORD.

The variations of personal equation with the magnitude of the stars observed has been studied chiefly for chronographic transits, and in what follows I shall attempt to add a little to what is known respecting this variation for eye-and-ear transits. This paper will give the results of a reconsideration of Prof. Bauschinger's experiments with screens detailed in Vol. 2 of the *Neue Annalen der Sternwarte in Bogenhausen bei München*, page xxv.

Prof. Bauschinger in this volume gives the places for 1880.0 of more than 10,000 stars (13200 single observations) observed by himself between 1884 and 1889. To determine the variation in question he observed a number of stars in 1891, both with screens *von "Schwarzem Crepe" oder "mattschwarzem Kattun."*

The "*crepe*" diminished the light by 4.5 magnitudes, and was employed for the fainter stars; the "*Kattun*" reduced the light about 7 magnitudes, and was employed for the brighter stars. The mean magnitudes without and with the screens are given for the four dates of observation.

Date	No. Stars	Bright—Faint		Mean Mag. Without Screen	Mean Mag. With Screen
1891 Jan. 29	10	$-0^s.036$	$\pm 0^s.040$	3.3	8.4
31	10	$+0.061$	± 0.024	3.1	9.1
Feb. 5	10	-0.012	± 0.032	3.0	8.5
7	9	-0.012	± 0.010	2.6	8.3

Combining these according to their mean errors we obtain

$$\text{Bright–Faint} = +0^s.016 \ \pm 0^s.016$$

and this apparently justifies Prof. Bauschinger's conclusion, "*dass ein nennenswerther persönlicher Fehler in der Schätzung der Durchgänge von Sternen verschiedener Grössenklassen für mich nicht vorhanden ist.*"

But it will be noticed that the observations of Jan. 31 indicate a discontinuity for stars of the apparent screened magnitude 9.1. For all the other dates, Jan. 31, Feb. 5 and 7, the screened stars are well within the range of easy observations with the Munich meridian circle (109mm in aperture) but for the excepted date the stars are faint enough to be rather difficult of observation in bright field through the screen. The phenomenon here indicated that faint stars are observed too early under similar circumstances was noticed by Argelander, *Bonner Beobachtungen*, Vol. VI, p. xii.

Prof. Auwers has confirmed, and in fact more than confirmed Argelander's remark on his own methods: See A.G.C., Berlin, A. p. (92).

In a similar way he states, p. (90), that the comparison of Auwers with Bauschinger indicates that Bauschinger also observed the faint stars $0^s.08$ too early relatively to the brighter ones, $0^s.079 \ \pm 0^s.031$, as the combination of the

three dates, Jan. 29, Feb. 5, 7, would indicate by comparison with Jan. 31, as Prof. AUWERS has calculated, and, as I infer, correctly.

Prof. BAUSCHINGER's inference, then, as to his own right-ascensions needs to be slightly modified. His observations indicate the "Argelander-phenomenon," not only from the screen-results, but also from the comparison with Prof. AUWERS's Berlin zone. The rather tempting inference that the *Helligkeitsgleichung* is always such that the fainter stars are observed later than brighter ones is not confirmed by the collection of such data on page (133) of Prof. AUWERS's Berlin zone, nor by other similar investigations, so far as the writer is aware.

The indication that the personal equation depends very little on magnitude, when the eye-and-ear method is used, is by no means a certain proof that the fact is so; but at any rate can be tested more thoroughly by additional observations of the brighter stars through screens, and by the method of BRADLEY both with and without screens. Stars of the 8^M for an object-glass of 11–12cm cannot but furnish valuable information if their observation is made by eye-and-ear, and at once repeated chronographically. If, as seems likely, the personal equation depending on magnitude can by good observing be reduced to small importance, this fact would be a desirable one to show forth. A completed and published zone of the A.G.C., for which a repetition of the observations would be instructive, is that from 65° to 70°. The late eminent director of the Christiania Observatory, to whom the observations of the right-ascensions of this zone were due, was a pupil of ARGELANDER's, and his observations were excellent of their kind, and a repetition of a portion of them within a few years would be by no means a wasted labor with reference to the Greenwich photography in that zone.

Williams College Observatory, 1898 *March* 14.

MAXIMA AND MINIMA OF LONG-PERIOD VARIABLES,

BY J. A. PARKHURST.

267. *V Andromedae.*

Since the maximum reported in *A.J.* 412, I have followed this star closely. It fell rapidly from $10^M.0$, 1897 Aug. 27, to my limit, $12^M.8$, Oct. 25, the last magnitude of decrease occupying 20 days. It remained below my limit more than 3 months, on 1898 Jan. 18 being less than $12^M.1$, and was seen Feb. 15 at $11^M.4$. The rise was then rapid, reaching $10^M.2$ on Mar. 4. The form of the light-curve suggests a minimum 1897 Dec. 20 ±10 days, at a magnitude considerably below 13, perhaps as low as 14.

294. *W Cassiopeae.*

I have 19 observations of this star since the minimum reported in *A.J.* 405, showing a steady rise to a maximum, $8^M.3$, 1897 Oct. 1; followed by a more rapid fall to $10^M.5$ 1898 Jan. 18.

659. *X Cassiopeae.*

Since the minimum noticed in *A.J.* 412, I have 20 observations between 1897 May 3 and 1898 Feb. 3. The rise was slow and irregular to a maximum at $10^M.1$, 1897 Oct. 21, after which the fall was a little more rapid, reaching $11^M.2$ at the last observation.

2815. *U Geminorum.*

I have the following observations of the last maximum:

Gr. M.T.		
1898 Feb. 2.50	not seen, limit $12^M.5$	
3.54	$11^M.8$±	moon
5.54	9.70	bright moon
6.56	9.55	moon, poor
15.52	10.55	thin clouds

The maximum was evidently of the "long" type, and probably occurred within a day or two of Feb. 8.

6100. *RV Herculis.*

I first saw this star 1897 Aug. 23, at $9^M.5$. It fell rapidly, till on Oct. 1 it was $12^M.4$, at which time it was falling a magnitude in 12 days. It then remained below my limit ($12^M.8$) for 3½ months. It was next seen 1898 Jan. 18 at $12^M.4$, and by Feb. 24 it had risen to $10^M.3$. The rapid fall at the time of disappearance, and the still more rapid rise at reappearance, indicate a magnitude at minimum as low as 14^M, the time of minimum being probably within a week or two of 1898 Dec. 1. I have 27 observations in all.

6449. *T Draconis.*

I have 23 observations of this star between 1897 May 3 and 1898 Mar. 6. It fell slowly and irregularly from $8^M.0$ to a minimum, $12^M.2$, on 1897 Dec. 17, and rose to $10^M.1$ at the last observation. It was fainter than the $10^M.5$ companion-star from Oct. 15 to Feb. 15, as compared with 3 months at the 1896-minimum.

6549. *W Lyrae.*

Since the maximum reported in *A.J.* 426 I have 7 observations, showing a minimum at $12^M.5$ on 1898 Jan. 29. The rise was a little more rapid than the decline, the star reaching $10^M.5$ at the last observation, Mar. 2.

7492. *RZ Cygni.*

The present series began 1897 May 28 and includes observations on 17 dates, ending 1898 March 6. The star fell very slowly from $11^M.3$ to a minimum, $12^M.7$, on 1897 Oct. 24, then rose more rapidly to $10^M.3$ at the last observation.

7792. *SS Cygni.*

This star has two types of maxima like those shown by *U Geminorum.* At the "short" maxima it remains above normal 12 or 13 days, at the "long" maxima. 18 or 19 days. The January maximum belonged to the "long" type, as shown by the following observations:

1898, Gr. T.	M	1898, Gr. T.	M
Jan. 5.50	11.30	Jan. 26.50	8.81
16.50	10.95	27.54	8.88
17.52	8.78	29.52	8.88
18.52	8.72	31.50	9.43
19.00	8.65	Feb. 2.50	10.28
20.50	8.53	3.52	10.83
23.50	8.84	5.52	11.45±

The maximum seems to have occurred Jan. 20.5 at $8^M.5$, though from the flatness of the curve, it could be a day later. The last magnitude in the list, 11.45. the lowest so far recorded, depends on but one comparison in poor seeing.

7896. *V Pegasi.*

The season's observations began 1897 July 1, when the star was not seen, being below 11^M. It remained below my limit during July, Aug. and Sept., and was first seen Oct. 30, at $11^M.8$. It rose steadily to a maximum, $9^M.1$, on 1897 Dec. 13, then fell more slowly to $10^M.6$ at the last observation, 1898 Jan. 23. The interval between this curve and the corresponding magnitudes, reported in *A.J.* 405, is about 304 days.

8324. *V Cassiopeae.*

Since the maximum reported in *A.J.* 426 I have 12 observations, giving a minimum, $12^M.6$, on 1898 Jan. 11. The curve is regular and the period exceptionally constant.

OBSERVATIONS OF VARIABLES.

By JOSEF MALÍŘ.

[Communicated by Prof. G. GRUSS.]

The observations were made by means of the 8-inch refractor of the Astronomical Institution of the Bohemian University in Prague, and extend from 1896 November 26 to 1897 September 8. The first part of the observations give very uncertain results because the measurements were disturbed by the unfavorable season, especially in the months of December, January and March.

The magnitude of the comparison-stars was deduced by means of a scale of the author, which was adjusted to *Bonner Durchmusterung* in a manner analogous to that used by Müller and Kempf, in Potsdam, for their fundamental stars.

Results of Observations; Observed Maxima and Minima.*

No. (Ch.)	Star	Phase	Mag.	Step	Observed Date Julian	Calendar 1897
1574	*W Tauri*	Max.	8.9	0.07	–	At the end of January
1577	*R Tauri*	Max.	9.0	0.08	241 3938	January 13 $\pm 10^d$
1800	*W Orionis*	Max.	5.9	0.10	–	At the end of Dec., 1896, or at the beginning of Jan., 1897
2100	*U Orionis*	Max.	6.0	0.17	3995	March 11 $\pm 3^d$
3567	*V Leonis*	Max.	8.8	0.08	4008	March 24 $\pm 6^d$
4948	*R Can. Venat.*	Max.	7.3	0.12	4065	May 20
5174	*RS Virginis*	Max.	7.6	0.12	3987	March 3
5758	*X Herculis*	Min.	6.5	0.16	–	At the end of July, or at the beginning of August
6449	*T Draconis*	Max.	7.7	0.15	4019	April 4 (secondary maximum?)
6682	*X Ophiuchi*	Max.	6.7	0.15	4092	June 16 $\pm 5^d$
6900	*W Aquilae*	Max.	8.4	0.11	4093	June 17 $\pm 15^d$
6943	*T Sagittae*	–	–	0.13	–	Nearly constant
7118	*X Aquilae*	Max.	8.9	0.10	4072	May 27 $\pm 5^d$
7456	*RR Cygni*	Max.	8.6	0.10	–	In the half of June
7783	*RU Cygni*	Min.	8.8	0.15	241 4164	August 27 $\pm 5^d$
8324	*V Cassiopeae*	Max.	>7.2	0.12	–	After September 8

* The article was accompanied by a voluminous statement of the data of the individual observations, which is omitted for want of space. — Ed.

Astronomical Institution of the Bohemian University, Prague VII 80, 1898 February 15.

A NEW VARIABLE OF PRESUMABLY VERY LONG PERIOD,

By G. MÜLLER and P. KEMPF.

The star B.D. +30°591, which was to be used as a fundamental star for the Potsdam *Durchmusterung*, has turned out to be a variable of so unusual a character as to render the case one of special interest. From 1888 to 1891 the star was constant, magnitude 6.31; from 1891 to 1894 we did not observe it; but since the beginning of 1894 it has decreased regularly by one-eighth of a magnitude every year, so that now it has already lost $0^{m}.6$ in brightness. We have made measures at every available opportunity for some years, and have now obtained altogether about 160 observations, which will be published in the *Astr. Nachr.* By grouping the measures according to observation-seasons, the star being visible from August to April, we obtain the following mean values.

Dates of Observation	No. Measures	Magnitude
1888 Feb. 25 – 1891 Feb. 13	50	6.31
1893 Nov. 9 – 1894 Mar. 24	5	6.44
1895 Feb. 8 – 1895 Apr. 2	9	6.60
1895 Sept. 26 – 1896 Apr. 2	41	6.69
1896 Aug. 28 – 1897 Apr. 9	28	6.82
1897 Aug. 18 – 1898 Mar. 20	26	6.92

Presumably we have here to deal with a binary system, in which one star is at present transiting across the other.

Potsdam, Astrophysical Observatory, 1898 *April* 5.

COMETS OF THE YEAR 1897.

The dates are in Greenwich Mean Time and the Elements only approximate.

Designation	Perihelion	☊	ω	i	q	φ	Discoverer	Date	Synonym	
		° ′	° ′	° ′		° ′		1896–97		
I	1897 Feb. 8.14	86 18	172 21	146 8	1.0623	. .	Perrine	Nov. 2	*f* 1896	
II	May 23.94	146 21	173 4	15 44	1.3212	38 51	Perrine	June 28	*a* 1897	D'Arrest's
III	Dec. 8.55	32 3	65 49	69 36	1.3573	. .	Perrine	Oct. 16	*b* 1897	

EPHEMERIS OF WINNECKE'S COMET, *a* 1898,

By C. HILLEBRAND.

(*A.N.* 3482): For Berlin Midnight.

1898	α	δ	log. Δ	1 : $r^2\Delta^2$	1898	α	δ	log. Δ	1 : $r^2\Delta^2$
	h m s	° ′				h m s	° ′		
Apr. 28.5	0 11 28	−7 5.4	0.2198	0.31	May 18.5	1 14 23	−3 26.1	0.2524	0.20
May 2.5	25 8	6 18.8	.2269	.28	22.5	25 27	2 47.7	.2578	.18
6.5	38 13	5 33.2	.2338	.26	26.5	36 6	2 11.7	.2628	.17
10.5	0 50 46	4 49.0	.2403	.24	30.5	46 17	1 38.1	.2675	.16
14.5	1 2 50	−4 6.5	0.2465	0.22	June 3.5	1 56 4	−1 7.0	0.2717	0.14

SEARCHING EPHEMERIS FOR ENCKE'S COMET,

By DAVID SMART.

(*Observatory*, No. 265): For Greenwich Midnight.

1898	α	δ	1898	α	δ	1898	α	δ
	h m s	° ′		h m s	° ′		h m s	° ′
April 30.5	3 3 20	+22 48	May 16.5	4 35 20	+24 46	June 1.5	6 10 2	+18 18
May 4.5	23 12	23 40	20.5	5 4 38	24 7	5.5	25 21	15 11
8.5	3 45 24	24 18	24.5	28 48	22 58	9.5	39 15	11 33
12.5	4 9 20	+24 49	28.5	5 51 30	+21 3	13.5	6 53 14	+ 7 11

Perihelion passage May 24. Greatest brightness July 3.

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GENERAL THEORY OF THE ABERRATION IN THE FOCAL PLANE OF A PARABOLIC REFLECTOR,

By J. M. SCHAEBERLE.

In the present article, which is to be regarded as a continuation of my paper in *A.J.* 413, I have derived the general rigorous expressions for the focal plane coordinates of *any* ray of starlight reflected from any point of a parabolic surface.

The method of derivation of the various formulas can be more readily followed with the aid of the accompanying diagram.

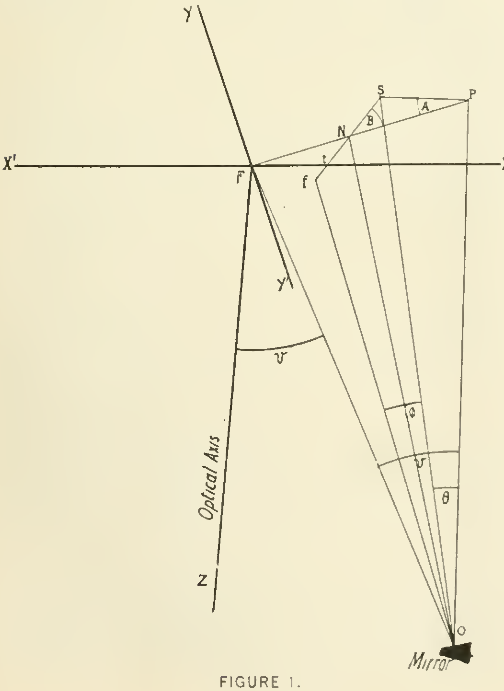

FIGURE 1.

Let O be any point of the mirror's surface at which the reflection takes place.

" $OF = \rho$ denote the distance of this point from the principal focus.

" $FOP = OPZ = v$ denote the angle, at the focus, between the optical axis and a line drawn to O.

" $SOP = \theta$ denote the angle which the direct ray makes with the line OP drawn parallel to the optical axis.

Let the focal point be the origin of coordinates, the plane of XY coinciding with the focal plane.

For brevity let the line of intersection of any given plane with the focal plane be called the *trace* of the given plane.

Let the trace (XFX') of the plane containing the optical axis and the direct rays of light parallel to SO be taken as the axis of X, and let the x-coordinate of the image be positive.

Let $PFX = SPF = A$ be the angle which the trace of the plane containing the optical axis and the point O makes with the axis of X: A having any value between 0° and 360°.

Let $SNP = B$ be the angle which the trace of the plane of incidence and reflection makes with the trace PF: then $StX = A + B$. These two planes (traces PF and Sf) intersect in a line NO which is normal to the reflecting surface at the point O, and consequently bisects the angle $POF = v$: and also the angle $SOf = \phi$ included between the direct ray SO and the reflected ray Of.

For a given value of v this normal (NO) makes the fixed angle $ONP = 90° - \frac{1}{2}v$ with the trace PF, and a variable angle $ONS = I$ (which is a function of A, v and θ) with the trace Sf.

It is required to find the rigorous general expression for the focal plane coordinates of the point f, having given A, v, θ and ρ ($= F\sec^2 \frac{1}{2} v$).

Referring now to Fig. 1, we have

(1) $PO = \rho \cos v$

(2) $SO = \rho \cos v \sec \theta$

(3) $PS = \rho \cos v \tan \theta$

(4) $ON = \rho \cos v \sec \frac{1}{2} v$

(5) $NF = \rho \cos v \,(\tan v - \tan \frac{1}{2} v) = \rho \tan \frac{1}{2} v$

In the plane triangle SPN two sides and the included angle A are given, hence

(6) $SN = \rho \cos v \sqrt{\tan^2 \frac{1}{2} v + \tan^2 \theta - 2 \tan v \tan \theta \cos A}$

We next find the angle B from

(7)
$$\sin B = \frac{PS . \sin A}{NS} = \frac{\tan \theta \sin A}{\sqrt{\tan^2 \frac{1}{2} v + \tan^2 \theta - 2 \tan v \tan \theta \cos A}}$$

As the trace Sf makes the angle B with the trace PF, the expression for the inclination $I = SNO$ of the normal to the trace Sf becomes

(8) $\cos I = \sin \frac{1}{2} v \cos B$

To obtain an expression for the value of the angle $SOF = \phi$ we have given two sides and the included angle I of the triangle NOS, hence

(9)
$$\sin \tfrac{1}{2} \phi = \frac{NS \sin I}{SO}$$
$$= \sin I \cos \theta \sqrt{\tan^2 \tfrac{1}{2} v + \tan^2 \theta - 2 \tan \tfrac{1}{2} v \tan \theta \cos A}$$

In the plane triangle NOf the length of the normal NO and all the angles are known, therefore

(10)
$$NF = \frac{NO \sin \frac{1}{2} \phi}{\sin (I - \frac{1}{2} \phi)} = \rho \frac{\cos v \sec \frac{1}{2} v \sin \frac{1}{2} \phi}{\sin (I - \frac{1}{2} \phi)}$$

By multiplying the second member of eq. (10) by $\cos [180° + (A+B)]$ and $\sin [180° + (A+B)]$, respectively, we obtain the x'' and y'' coordinates of the point f referred to N as an origin.

Let x' and y' denote the coordinates of the point N referred to the point where the optical axis pierces the focal plane, then

(11) $x' = FN \cos A = \rho \tan \frac{1}{2} v \cos A$

(12) $y' = FN \sin A = \rho \tan \frac{1}{2} v \sin A$

Let the focal plane coordinates of the point f referred to the optical axis be x and y, then

(13) $x = x' + x''$

(14) $y = y' + y''$

Substituting, and writing $F \sec^2 \frac{1}{2} v$ in place of ρ, we obtain, finally, the following general and wholly rigorous expressions for the focal plane coordinates of the point f expressed in terms of the principal focal length F.

(15)
$$\frac{x}{F} = \sec^3 \tfrac{1}{2} v \left[\sin \tfrac{1}{2} v \cos A + \frac{\cos v \sin \frac{1}{2} \phi \cos (180° + A + B)}{\sin (I - \frac{1}{2} \phi)} \right]$$

(16)
$$\frac{y}{F} = \sec^3 \tfrac{1}{2} v \left[\sin \tfrac{1}{2} v \sin A + \frac{\cos v \sin \frac{1}{2} \phi \sin (180° + A + B)}{\sin (I - \frac{1}{2} \phi)} \right]$$

I have computed two sets of values of $\frac{x}{F}$ and $\frac{y}{F}$ for every 15° of A from 0° to 360°. The resulting coordinates were plotted and a smooth curve drawn through the several points (see Fig. 2). One set corresponds to the constant values of $v = 3°$ and $\theta = 30'$, and gives the smaller one of the two closed curves. The heavier (larger) curved figure corresponds to the constant values $v = 5°$ and $\theta = 30'$.

Each curve is therefore the locus of the intersections with the focal plane of the rays reflected from the successive points of a narrow annular ring whose angular radius (as seen from the focal point) is v; the direct rays being parallel and inclined 30′ to the optical axis.

A study of the relative size and position of the two curves (with reference to the point where $v = 0°$, $\theta = 30'$) shows in a striking manner the rapid increase in the radial distortion of the image for increasing values of v and the accompanying rapid increase in the transverse distortion when v is large and increasing.

The approximate law of distribution of the intensity of the light in the complete focal plane image can also be deduced from a consideration of the position and relative size of each image (as formed by different concentric rings of the reflecting surface) with reference to the size and position of an assumed unit-area and intensity formed by a small central area of the mirror.

The formulas and figure show that practically all the light coming from a small unit-area having an angular radius of, say, $v = 1°$ (corresponding to a ratio of focal length to aperture of about 28 to 1) can be said to lie within a focal plane area of one square second of arc, which will be taken as the unit-area in the focal plane. Let this particular unit-area have a mean intensity equal to unity.

Now for $v = 3°$ the total increase in the amount of light is approximately $3^2 - 1^2 = 8$; while the total increase in the focal area over which the light is spread (found approximately by adding to the number of squares contained in the smaller closed curve, the number contained between this curve and the two tangent lines drawn from the point for which $v = 0°$) is $9 - 1 = 8$. Therefore, if the light were uniformly distributed, the intensity for $\theta = 30'$ of the focal plane image formed by reflection from the zone of the mirror included between the radii $v = 1°$ and $v = 3°$ would be practically the same as the unit-intensity, although the total amount of light is actually eight times as great. An inspection of the figure, however, plainly shows that for moderate values of v the image formed by an annular ring of sensible width will be brightest on the side towards the optical axis; but as only a portion of the central area is covered by a small but more condensed part of the image formed by reflection from an annular ring-area whose radii are 1° and 3°, only a slight gain in intensity of the central unit-area results from the additional zone.

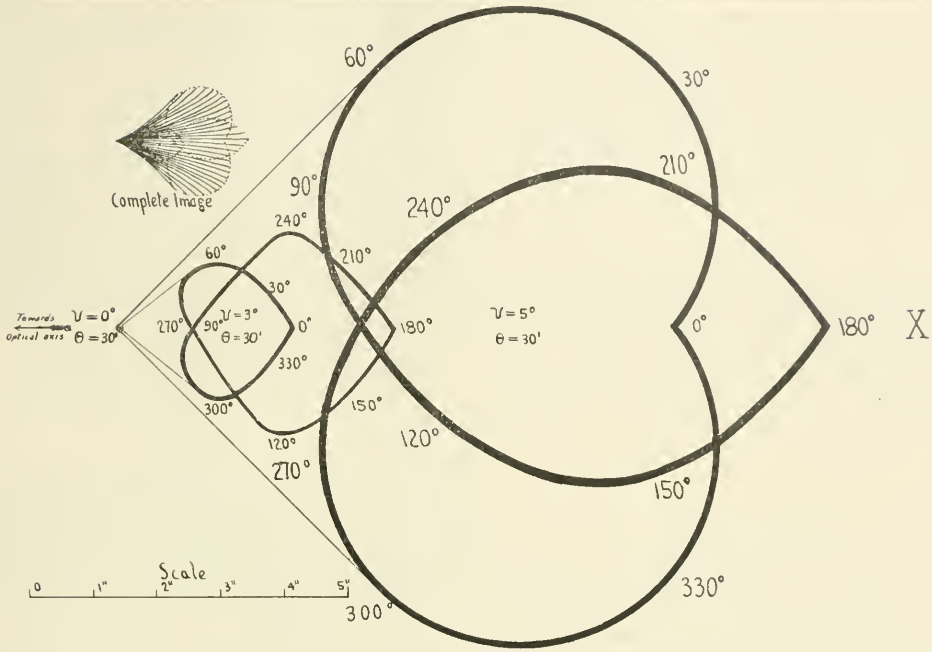

FIGURE 2.

Considering now the image formed by a zone of the mirror's surface included between the radii $v = 3°$ and $v = 5°$, we see at once that no part of the resulting image can overlap the central unit-area when θ is as large as $30'$. Consequently no increase in the intensity of the central unit-area can result, however great the value of v may become.

The increase (over the central area) in the total amount of light reflected is $5^2 - 3^2 - 1^2 = 15$, while the increase in the area over which the image is spread is about sixty times the unit-area; giving a mean intensity only one-fourth as great as the unit-intensity, for fifteen times the amount of light.

The typical "complete image" (for $v = 5°$ and $\theta = 30'$) formed by reflection from all the rings of which the mirror's surface may be said to be made up, is approximately of the form and relative intensity shown in the smaller diagram of Fig. 2.

As far as I am aware the coordinates given by equations (15) and (16) differ quite radically from any focal plane coordinates heretofore deduced. It would seem, therefore, that the claim I made, and still maintain, that certain fundamental principles of optics had, up to the present time, been overlooked in the theory of the parabolic reflector, is confirmed by the results of the general theory here developed.* The principal oversight in the past has, according to my view, been the neglect to consider in a consistent manner the relation existing between F and ρ for different values of v.

I shall now discuss, very briefly, equations (15) and (16) for certain special values of v, θ and A.

(a) Let $v = 0$. For this condition the points P, N and F must evidently coincide; S must, therefore, lie upon the axis of x, and consequently A must be zero. Equations (7), (8) and (9) also show that $B = A = 0$, $I = 90°$ and $\frac{1}{2}\phi = \theta$, hence (15) and (16) become

$$\frac{x}{F} = \tan\theta \qquad (17)$$

$$\frac{y}{F} = 0 \qquad (18)$$

The geometrical image in this case is simply the point where a single ray of light pierces the focal plane. It is the only part of the focal plane image of a star which has no aberration, and *it is always nearer to the optical axis*

* This remark is called forth by two papers in *Popular Astronomy* for February, 1898, written by the same author. For my reply to the same see *Popular Astronomy* for March, 1898.

than any other part of the star-image formed by the whole mirror.

(*b*) Let $\theta = 0$. Equations (7), (8) and (9) show that for this case $B = 0$, $I = 90° - \frac{1}{2} v$ and $\frac{1}{2}\phi = \frac{1}{2} v$. These values substituted in the second members of (15) and (16) make the two terms within the brackets respectively equal to each other, hence

$$\frac{x}{F} = 0 \tag{19}$$

$$\frac{y}{F} = 0 \tag{20}$$

All the reflected rays, therefore, pass through the point where the optical axis pierces the focal plane.

(*c*) Let $A = 0$. Equations (7), (8) and (9) now show that for this case $B = 0$, $I = 90° - \frac{1}{2} v$ and $\frac{1}{2}\phi = \frac{1}{2} v - \theta$. Substituting in (15) and (16) we obtain after a few simple transformations.

$$\frac{x}{F} = \sin\theta \sec(v-\theta) \sec^2 \tfrac{1}{2} v \tag{20}$$

$$\frac{y}{F} = 0 \tag{21}$$

Referring to Fig. 2 we see that for $v = 3°$ the corresponding value of x is at a secondary maximum; while for $v = 5°$ it corresponds to a secondary minimum, at the apex of a re-entrant curve.

(*d*) Let $A = 180°$. The only difference, in the substitutions, between this case and the previous one is that now $\frac{1}{2}\phi = \frac{1}{2} v + \theta$. The resulting equations are

$$\frac{x}{F} = \sin\theta \sec(v+\theta) \sec^2 \tfrac{1}{2} v \tag{22}$$

$$\frac{y}{F} = 0 \tag{23}$$

It is evident that there are other values of x which make $y = 0$ besides those corresponding to $A = 0°$ and $A = 180°$; for as the two terms of equation (16) *always* have opposite signs (except for the special cases $A = 0°$ and $180°$, already considered), and both terms pass through zero, it is evident that there must be at least two additional values of A which make the terms finite and numerically equal to each other. For a particular value $A = A_1$ less than $180°$ fulfilling this condition, the first term will be positive, and the second negative. The substitution of A_1 in (15) will give one value of $x = x_1$ which renders $y = 0$. An identical value $x_2 = x_1$ will result from the substitution of $A_2 = 360° - A_1$ in (15), since this value of A_2 will also make $y = 0$, the first term of (16) now being negative and numerically equal to the positive second term. In general, therefore, the locus of the point f crosses the axis of x at least four times, as y becomes equal to zero for $A = 0°$, $180°$, A_1 and A_2.

Figure 2 shows that both for $v = 3°$ and $v = 5°$ the value of x corresponding to $A = 180°$ is at a maximum. To prove that this condition holds true for all values of v and θ we know first of all that, as the coordinates of every reflected ray from a star exactly on the optical axis are given by equations (19) and (20), it follows that the x-coordinates of every reflected ray from a star at an angular distance θ from the optical axis must be *positive*, as the fixed normal to any point of the reflecting surface must always lie between the direct and reflected ray. Secondly, the two terms of equation (15) always have opposite signs, except when either one is zero, in which case the other is always a positive quantity. Consequently as x cannot be negative we have only to determine that value of A which makes the algebraic sum of the two terms a maximum positive quantity.

A simple inspection of (15) shows the numerator of the second term is a maximum and the denominator a minimum when $A = 180°$. For this value of A the factor $\dfrac{\cos v \sin\frac{1}{2}\phi}{\sin(I-\frac{1}{2}\phi)}$ is also much greater than $\sin\frac{1}{2}v$. Moreover, as $\cos(180+A+B)$ diminishes, numerically, more rapidly than $\cos A$ for values slightly greater or less than $A = 180°$, it follows that x is at its maximum possible value when $A = 180°$.*

The radial aberration is therefore a maximum in the plane containing the optical axis and the star whose image is under consideration.

The actual amount of the blurring can readily be found by means of the rigorous equation (22). The position of the image formed by the center of the mirror is at once obtained by making $v = 0$. Equation (22) then becomes

$$x_0 = F \tan\theta \tag{23}$$

Subtracting (23) from (22) we obtain the desired expression

$$x - x_0 = F \sin\theta \left[\sec(v+\theta) \sec^2 \tfrac{1}{2} v - \sec\theta\right] \tag{24}$$

A more convenient formula is the expression for what I have called the "blurring factor" found by *dividing* (22) by (23).

$$\frac{x}{x_0} = \text{Blurring Factor} = \frac{\cos\theta}{\cos(v+\theta)\cos^2\frac{1}{2}v} \tag{25}$$

Equation (22) can also be written

$$x = \rho \sin\theta \sec(v+\theta) \tag{26}$$

which corresponds with the formula (2) of my paper in *A.J.* 423, except that I there inadvertently wrote $\tan\theta$ instead of $\sin\theta$. With this wholly insensible correction equation (4) of the previously mentioned paper becomes identical with the above rigorous expression (25).

* There are other values of A which give secondary maxima values of x, but these need not be considered in the present paper; an inspection of Fig. 2 will show, in a general way, the location of maximum and minimum points for both x and y.

For telescopes of large angular aperture θ must always be very small if the best possible results are desired, so that for this case equation (25) reduces to the convenient approximate form already given in *A.J.* 413,

$$(27) \qquad \text{Blurring Factor} = \frac{1}{\cos v \cos^2 \frac{1}{2} v}$$

The law expressed by equation (24) gives, for any value of v and θ, the maximum distance through which the image, formed by any ring-area of the paraboloid, has shifted with reference to the image formed by the central reflecting area.

When v is large the *rate* of shifting for an infinitesimal value of θ is practically just as great as it is for any value of θ likely to be used in practice. Images of objects having sensible angular magnitudes will therefore necessarily be blurred. The *rate* of blurring is dependent directly upon the value of v, while the *amount* depends upon both v and θ.

Owing to the extremely limited size of the field of view (with the optical axis as a center), which can be used when results of great delicacy are desired, I am inclined to the belief that for mirrors of large angular apertures the Cassegrain form of telescope will eventually supersede the ordinary form for obtaining, on a large scale, photographic representations of celestial areas not much exceeding one or two minutes of arc in diameter. This opinion is based upon actual experimental results obtained at the Lick Observatory with different forms of telescopes.

Lick Observatory, University of California, 1898 March.

ON THE STAR-IMAGE FORMED BY A PARABOLIC MIRROR,

By H. C. PLUMMER.

The interesting papers which have been published recently on the subject of the aberration of parabolic mirrors, have only considered the rays which are incident in a plane passing through the axis of the mirror. It is proposed here to find the approximate form of the star-image in the focal plane, and to estimate the distribution of intensity.

For the surface of the mirror we take

$$4fx = y^2 + z^2 = r^2$$

Let the plane ZOX pass through the star, and let θ be its angular distance from the center of the field. Then the ray incident at (xyz) is

$$\frac{X-x}{\cos\theta} = \frac{Y-y}{0} = \frac{Z-z}{\sin\theta}$$

The normal at (xyz) is $\quad \dfrac{X-x}{-2f} = \dfrac{Y-y}{y} = \dfrac{Z-z}{z}$

Let the reflected ray be $\quad \dfrac{X-x}{\lambda} = \dfrac{Y-y}{\mu} = \dfrac{Z-z}{\nu}$

The laws of reflection give $\quad \begin{vmatrix} \lambda & \mu & \nu \\ \cos\theta & 0 & \sin\theta \\ -2f & y & z \end{vmatrix} = 0$

and $\qquad -2f\lambda + \mu y + \nu z = -2f\cos\theta + z\sin\theta$

Hence

$$\frac{\lambda - \cos\theta}{2fz\sin\theta + r^2\cos\theta} = \frac{\mu}{2fy\cos\theta - yz\sin\theta}$$
$$= \frac{\nu - \sin\theta}{(y^2+4f^2)\sin\theta + 2fz\cos\theta} = k, \text{ say.}$$

Eliminating λ, μ, ν between these three equations and

$$\lambda^2+\mu^2+\nu^2 = 1 \quad , \quad \text{we get} \quad k = \frac{-2}{4f^2+r^2}$$

Let $(\xi\eta\zeta)$ be the intersection of the reflected ray with the focal plane.

$$\therefore \xi = f \quad ; \quad \eta = y + \frac{\mu}{\lambda}(f-x) \quad ; \quad \zeta = z + \frac{\nu}{\lambda}(f-x)$$

Hence we obtain

$$\eta = \frac{-2yz(f+x)\sin\theta}{(4f^2-r^2)\cos\theta - 4fz\sin\theta}$$

$$\zeta = \frac{-\sin\theta\,\{4f^3+2fz^2-x(y^2-z^2)\}}{(4f^2-r^2)\cos\theta - 4fz\sin\theta}$$

These expressions are exact, but from this point powers of $\tan\theta$ above the first are neglected. Thus

$$\eta = -\frac{2yz(f+x)}{4f^2-r^2}\tan\theta$$

$$\zeta = -\frac{4f^3+2fz^2-x(y^2-z^2)}{4f^2-r^2}\tan\theta$$

But for the ray reflected at the vertex:

$$\eta_0 = 0 \quad ; \quad \zeta_0 = -f\tan\theta$$

Hence finally, neglecting x, which is small compared with f,

$$\eta - \eta_0 = -\frac{\tan\theta}{2f}yz$$

$$\zeta - \zeta_0 = -\frac{\tan\theta}{4f}(r^2+2z^2)$$

If we eliminate yz from these by means of $y^2+z^2 = r^2$, we obtain

$$(\eta-\eta_0)^2 + \left\{\zeta - \zeta_0 + \frac{r^2\tan\theta}{4f}\right\}\left\{\zeta - \zeta_0 + \frac{3r^2\tan\theta}{4f}\right\} = 0$$

as the locus of points in which the rays reflected from an infinitely narrow zone of the mirror cut the focal plane. This shows that the locus is a circle whose center is $\left(\eta_0 \cdot \zeta_0 - \dfrac{r^2\tan\theta}{2f}\right)$ and whose radius is $\dfrac{r^2\tan\theta}{4f}$.

Now, if F is the focus of the mirror, and O is the point $(f\eta_0\zeta_0)$, the lines through O which make angles of 30° with FO produced touch this circle, and similarly all the

circles formed by reflection from successive zones of the mirror. Hence the complete image is bounded by these two lines and by the circular arc to which the outside zone of the mirror gives rise. It is consequently kite-shaped, with the point directed towards the center of the field, as shown in Fig. 1. Its length is $\frac{3R^2}{4f}\tan\theta$ where $2R$ is the aperture, and its extreme breadth is $\frac{R^2}{2f}\tan\theta$.

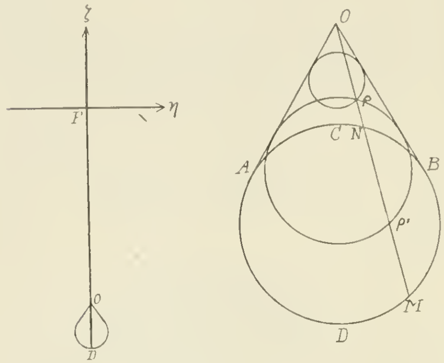

FIGURE 1.

From this way of considering the generation of the image, it is clear that there is a real difference between the areas $OACB$ and $ACBD$ (Fig. 1), for through every point of the former pass two images formed by distinct zones, while through every point of the latter there passes one only.

To consider the intensity in the area $ACBD$ first. Through the point $(\eta\zeta)$ pass the rays reflected at both the points (xyz) and $(x.-y.-z)$ as is clear from the expressions for $\eta-\eta_0$, $\zeta-\zeta_0$. Now the planes, $y, y+dy$, $z, z+dz$, include the area

$$\frac{\sqrt{r^2+4f^2}}{2f}\,dy\,dz$$

on the mirror, and the light incident on this area is proportional to

$$\frac{2f\cos\theta-z\sin\theta}{\sqrt{r^2+4f^2}}\;\frac{\sqrt{r^2+4f^2}}{2f}\,dy\,dz=\left(\cos\theta-\frac{z\sin\theta}{2f}\right)dy\,dz$$

Hence the light reaching $(\eta\zeta)$ from (xyz) and $(x.-y.-z)$ is proportional to $2\cos\theta\,dy\,dz$. But the ratio of $dy\,dz$ to the corresponding element of the image is $\frac{1}{J}$.

$$J=\begin{vmatrix}2y & 6z\\ z & y\end{vmatrix}\times\frac{\tan^2\theta}{8f^2}=(y^2-3z^2)\,\frac{\tan^2\theta}{4f^2}$$

Hence the intensity at $(\eta\,\zeta)$ is proportional to

$$\frac{8f^2\cos\theta}{(y^2-3z^2)\tan^2\theta}$$

Again, it is clear on inspection that $\eta-\eta_0$, $\zeta-\zeta_0$ are unaltered by substituting the point $\left(\pm\sqrt{3}z\pm\frac{y}{\sqrt{3}}\right)$ for $(y\,z)$. Hence the rays reflected at these points also pass through $(\eta\,\zeta)$ if $(\eta\,\zeta)$ lies within $OACB$. But the expression for the intensity is also unaltered by the substitution. This shows that the intensity in this part of the image is proportional to $\frac{16f^2\cos\theta}{(y^2-3z^2)\tan^2\theta}$.

Transforming to polar coordinates by putting

$$\eta=\eta_0-\rho\sin q\quad;\quad\zeta=\zeta_0-\rho\cos q$$

it is found that

$$y^2-3z^2=\frac{4f\rho}{\tan\theta}\sqrt{\frac{\cos 3q}{\cos q}}$$

Hence the intensity at the point $(\rho\,q)$ is proportional to

$$\frac{4f\cos\theta}{\rho\tan\theta}\sqrt{\frac{\cos q}{\cos 3q}}$$

if the point is within $OACB$ or to

$$\frac{2f\cos\theta}{\rho\tan\theta}\sqrt{\frac{\cos q}{\cos 3q}}$$

if the point is within the circle $ACBD$.

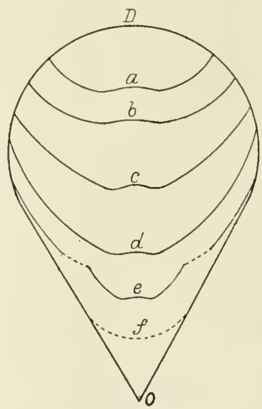

FIGURE 2.

These expressions have a simple geometrical representation. They are for the points ρ and ρ' (Fig. 1),

$$\frac{2R^2\cos\theta}{OP\,MN}\quad\text{and}\quad\frac{R^2\cos\theta}{OP'MN}$$

The isophotic curves are of the form $\rho^2\cos 3q=a^2\cos q$.

These results obtained from simple geometrical considerations are to be taken as very rough approximations only.

The intensity at each point is really due to two or four interfering streams of heterogeneous light, and diffraction effects have been ignored. At the same time, the expressions obtained may be expected to give a fair indication of the general distribution of intensity over the image, and in fact they seem to agree satisfactorily with the appearance of stellar images imprinted on the photographic plate. It is to be noted that the sharp bright point indicated by the theory, will in practice be wanting: for this is produced by the rays reflected at the central zones of the mirror, and this part. for an obvious reason, cannot be used. On this account the kite-shaped figure ought to be blunt instead of sharply pointed towards the center of the field. If the star is sufficiently faint (or the exposure sufficiently short) the part of the image remote from the center of the field will make only a faint impression on the sensitized plate and the resulting appearance will somewhat resemble that of a comet. If the star is fainter still, a certain part of the image will fail altogether to make any record on the plate. In that case the outer boundary of the resulting figure will be an isophotic curve, and it becomes apparent that there is a considerable variety of possible figures corresponding to a range of stellar brightness. These curves of equal intensity are roughly indicated in Fig. 2, in which a, b, c, d, e, are all possible bounding curves of the photographic impressions of stars of descending magnitude. The additional curve f in the same figure is intended to show the effect of the light intercepted by the plate itself in curtailing the image: an effect which is most pronounced near the center of the plate.

An inspection of the enlargements of photographs which Dr. ISAAC ROBERTS has taken with his parabolic reflector, suffices to show that these theoretical results, however imperfect and liable to certain objections, do express the truth with considerable accuracy. On this account the preceding investigation is perhaps not wholly devoid of interest.

Hertford College, Oxford, 1898 *March* 31.

ELEMENTS AND EPHEMERIS OF COMET *b* 1898,

BY WILLIAM J. HUSSEY.

From my observations of March 21, April 8 and April 22, I have computed the following elements and ephemeris of this comet. I attempted to reduce the residuals by computing other systems of elements from the same observations, using different values of the ratio of the curtate distances. Three other systems of elements were obtained, all very nearly the same as those given below. The residuals can not be materially improved; their ratio may be changed, but the sum of their squares can not be sensibly diminished. A careful examination of the data, including a comparison of the observations with others made at nearly the same time, does not reveal any error to explain the magnitude of the residuals.

ELEMENTS.

T = 1898 March 17.37195 Gr. M.T.

$$\left.\begin{aligned}\omega &= 47^\circ\,37'\,\;6''.2\\ \Omega &= 262\;\;33\;\;\;5.7\\ i &= \;\;72\;\;26\;\;56.1\end{aligned}\right\}\text{Ecliptic and Mean Equinox of 1898.0}$$

$\log q$ = 0.040916

$O-C$: $\Delta\lambda'\cos\beta = -4''.2$, $\Delta\beta = +12''.4$

CONSTANTS FOR THE EQUATOR OF 1898.0.

$$\begin{aligned}x &= r[9.513088]\sin(v+\;\;24^\circ\,10'\,47''.1)\\ y &= r[9.999991]\sin(v+293\;\;\;4\;\;41.1)\\ z &= r[9.975628]\sin(v+\;\;22\;\;56\;\;49.8)\end{aligned}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1898	True α	True δ	log Δ	Br.
	h m s	° ′		
May 9.5	1 20 37	+53 31.2	0.2957	0.40
13.5	1 41 54	+54 28.3	0.3082	0.36
17.5	2 2 37	+55 11.6	0.3204	0.32
21.5	2 22 37	+55 42.7	0.3323	0.29
25.5	2 41 55	+56 3.4	0.3438	0.26
29.5	2 59 57	+56 15.3	0.3549	0.23
June 2.5	3 17 11	+56 20.0	0.3655	0.21
6.5	3 33 25	+56 18.7	0.3756	0.19
10.5	3 48 42	+56 12.7	0.3851	0.17
14.5	4 3 1	+56 2.9	0.3941	0.15
18.5	4 16 26	+55 50.3	0.4025	0.14
22.5	4 29 00	+55 35.5	0.4103	0.13

The brightness at its discovery is taken as unity.

Mt. Hamilton, Cal., 1898 *April* 29.

OBSERVATIONS OF THE COMPANIONS OF *PROCYON*, AND OF β 883,

MADE WITH THE 40-INCH REFRACTOR OF THE YERKES OBSERVATORY,

BY E. E. BARNARD.

At the first favorable opportunity after the mounting of the 40-inch, *Procyon* was examined for the close companion discovered by Professor SCHAEBERLE with the 36-inch of the Lick Observatory. The companion was seen, during a few minutes of steadiness, in the position assigned it, but was lost in bad seeing before a single measure could be made. This was on November 2, 1897. It was not seen again until March 2 of this year (the intervening period being the worst possible portion of our observing year), when its position-angle was measured, but no distance

could be obtained, as it was seen for only a few minutes. On March 5 and 6 the companion was again seen, and good measures secured. On the latter date, when the seeing was good, it was a very conspicuous object and easy to measure with the bright star in the field unobscured. On this last date Professor HALE observed the companion with me, and was struck with its distinctness. Two sets of measures were made at this time, the first with *Procyon* occulted, the second with it unobscured. The second set is the best.

With good seeing the new companion is a singularly easy object in the 40-inch. When best seen it was estimated to be one magnitude fainter than the old companion, which is of about the 12th magnitude.

CLOSE COMPANION TO *Procyon*.

	°	″
1898.169	326.3	–
.178	324.9	4.87
.180	324.4	4.90
.180	326.4	4.83
.199	326.7	–
.257	–	4.69
.262	327.6	4.83
1898.279	325.4	4.88
1898.213	326.0	4.83

The old companion was also measured on four nights while looking for the close companion.

Yerkes Observatory, Williams Bay, Wis., 1898 *May* 6.

DISTANT COMPANION TO *Procyon*.

	°	″
1898.008	341.4	57.65
.011	341.3	57.77
.049	341.6	57.46
1898.169	341.8	57.55
1898.059	341.54	57.61

THE DOUBLE STAR β 883.

This star was discovered by Mr. BURNHAM, at Chicago, with the 18½-inch, in 1879. The present observations with the 40-inch were suggested by Dr. SEE's paper in *M.N.*, LVII, June, 1897, in which he assigns the star a period of 5½ years.

	°	″
1897.733	30.8	0.21
.744	32.1	0.19
.747	32.5	–
1897.840	35.4	0.21
1897.766	32.7	0.21

In the third observation the seeing was too poor to permit distance-measures. The two stars are sensibly equal in brightness.

During these measures the 13ᴹ companion, south following, was measured on one night.

A, *B* AND *C*.

	°	″
1897.744	154.7	17.74

ELLIPTIC ELEMENTS OF COMET *b* 1898,

BY C. D. PERRINE.

From the following observations of this comet —

1898 Mt. Hamilton M.T.	App. α	App. δ
	h m s	° ′ ″
March 19 16 47 21	21 18 36.89	+16 43 23.3
April 8 16 19 7	22 41 0.88	+36 20 50.5
April 28 15 26 54	0 23 20.68	+49 41 32.4

I computed a set of parabolic elements as follows:

$$T = 1898 \text{ March } 17.35984 \text{ Gr. M.T.}$$

$$\left.\begin{aligned}\pi &= 47^\circ\ 36'\ 8''.0\\ \Omega &= 262\ 32\ 26.3\\ i &= 72\ 26\ 50.4\end{aligned}\right\}1898.0$$

$$\log q = 0.040820$$

The residuals for the middle place being

$$\text{Obs.}-\text{Comp.}\quad \Delta\lambda\cos\beta = -14''.7 \qquad \Delta\beta = +22.4$$

Using the same three observations, I then obtained the following elliptic elements:

Epoch 1898 March 20.0 Gr. M.T.

$$M = 0^\circ\ 0'\ 34''.1$$

$$\left.\begin{aligned}\pi &= 47\ 14\ 48.8\\ \Omega &= 262\ 24\ 42.9\\ i &= 72\ 32\ 55.8\end{aligned}\right\}1898.0$$

$$\log q = 0.039179 \quad \log a = 1.656386 \quad \log e = 9.989386 \quad \log \mu = 1.065428$$

$$\varphi = 77^\circ\ 23'\ 3''.5$$

$$\text{Period} = 305.208 \text{ years}$$

The residuals for the three places used are

$$\text{Obs.}-\text{Comp.}\quad \alpha = -1''.2 \quad -0''.3 \quad +0''.5$$
$$\delta = +1.1 \quad -1.2 \quad +1.1$$

The constants for the equator of 1898.0 are

$$x = r[9.512253]\sin(23^\circ\ 17'\ 43''.4+v)$$
$$y = r[9.999997]\sin(292\ 39\ 52.2+v)$$
$$z = r[9.975717]\sin(22\ 35\ 22.6+v)$$

The comet has retained its brightness with but little change until within the past week, when it has begun to fade rapidly. It still retains its stellar nucleus, which is growing fainter, however, and is now not brighter than 10ᴹ.

Lick Observatory, University of California, 1898 *May* 4.

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MEASURES OF THE SATELLITE OF *NEPTUNE* WITH THE 40-INCH REFRACTOR OF THE YERKES OBSERVATORY, WITH REMARKS ON THE GREAT TELESCOPE,

By E. E. BARNARD.

The Forty-Inch Telescope.

The following observations of the satellite of *Neptune* are a continuation of my work on this object previously made with the 36-inch refractor of the Lick Observatory, which has already been printed in *A.J.* 342.

The winter here has been very trying for visual observations with the great telescope, and the seeing much of the time has been very poor. The satellite was often faint and difficult through the blurring of its light, though under ordinary conditions it is a bright object with a large telescope. On several occasions when the seeing was fairly good it was a strikingly conspicuous object. The opposition of *Neptune* now falls in the worst possible portion of the year for observation here. The above remarks therefore must not be supposed to bear upon any other portion of the year's observations at this observatory.

In the summer there are many very quiet and beautifully steady nights in which it is expected the great telescope will work to the very best advantage.

Actual work with the 40-inch was not possible until the best season was essentially over here. The occasional observations of the fifth satellite of *Jupiter*, of the close companion to *Procyon* and a few similar objects, show that even a part of this unfavorable weather may permit the power of the telescope to be seen. The work, however, in the main, has been confined to the lower powers. On one or two occasions, when observing double stars, it has been possible to use powers of several thousand diameters, and on one date a power of 3750 was used with good success.

The telescope is supplied with a set of very fine eyepieces, made especially for it by Steinheil of Munich. Following are approximate magnifying powers and the fields of view of these eyepieces:

No. 1	Mag. power =	230	Diam. of field =	396
2	" "	280	" "	395
3	" "	350	" "	376
4	" "	460	" "	240
5	" "	700	" "	153
6	" "	940	" "	116
7	" "	1340	" "	64
8	" "	1700	" "	53
9	" "	2080	" "	–
10	" "	2680	" "	33
11	" "	3750	" "	28

No. 4 is the most convenient of these eyepieces. This eyepiece and No. 5 were employed in the measures of the satellite of *Neptune*, the higher power being used when the atmosphere would permit it. During these measures no definite markings were seen on the planet, though on one occasion some details were suspected.

In all my work with the 40-inch, with the different magnifying powers, the object-glass seems to be entirely free from any form of ghost, and the definition, when the air permitted it, has always been very good, showing that this last great work of Alvan Clark is one of his noblest monuments.

The splendid micrometer by Warner & Swasey — to whom are due all the mechanical portions of the telescope — has proved eminently satisfactory. It is extremely convenient, and is supplied with arrangements for both oil and electrical illumination — which is by Burnham's method. Oil, so far, has been used with it, but arrangements are now being made to use the electrical illumination.

The designs for the micrometer were submitted, by Messrs. Warner & Swasey, to Mr. Burnham's unexcelled judgement, for criticism. In its design it therefore has had the advantage of what his practical experience could suggest, which has added much to the impor-

tance of its construction. The driving clock of the 40-inch has proved all that could be desired. Indeed, it is astonishing with what perfect steadiness this clock carries the great tube. This makes micrometer work with it particularly gratifying. The clock automatically winds itself at intervals of $1^h\ 48^m$, and requires five minutes for the winding. So stable is the mounting of the telescope that the effect of this winding is scarcely perceptible in the observations, so that micrometer work is not in the least interfered with while the clock is being wound. The stability of the entire instrument is very remarkable, and, considering its great size, the flexure of the tube is very small, as shown in the observations for adjustment of position. Besides hand clamps and slow motions, the telescope is also supplied with similar electrical contrivances at the eye-end, and it is astonishing to see with what perfect instantaneousness the clock takes up the tube upon the application of the electric clamp in right-ascension. The electric slow motions are controlled at the eye-end. They move the telescope slowly in right-ascension and declination. Their motion is beautifully steady. So exact are they that a star can be brought from the edge of the field and stopped instantly behind the micrometer-wire, the motion being about $1'$ in 8 seconds.

One gets the impression from the bigness of the instrument that it must necessarily be clumsy to handle. Through the aid of the electric motors, however, it can be pointed to different parts of the sky with remarkable ease. Some experiments of the quickness with which it can be reversed will show this. The instrument was placed on the west side of the pier, and pointed to the meridian at declination $+50°$. With the electric quick motors it was placed in a similar position on the east side of the pier in $1^m\ 50^s$. These motors are controlled by cords hanging down the north side of the pier, which are always within easy reach with the floor in any position.

The floor and dome are moved by electric motors. The control boxes for these motors are conveniently placed on the floor close to the north end of the pier. The dome, 90 feet in diameter, moves through a complete revolution in 6 minutes, while the floor descends through its full path of 22 feet in 3 minutes, and rises in $3\frac{3}{4}$ minutes. The speed of both floor and dome can be regulated to suit the observer, but the above values are considered the safest speed.

A very highly important addition to the dome is a windbreak. The telescope is protected from the wind (which is almost incessant here during the winter months) by canvas curtains moving in the observing slit. Without these curtains micrometrical work would be very badly interfered with. With them, unless one is observing at a low altitude and right in the face of the wind, the tube can always be perfectly protected, even in the windiest nights. There are two of these curtains, working on endless chains; one rising from the base of the slit, the other passing through the zenith from the rear. This latter is very useful if a heavy dew is falling.

Take it all in all, for micrometrical work, when the atmospheric conditions are good, this is by far the most satisfactory instrument I have yet seen.

A rather singular incident occurred in the early use of the instrument which may be interesting here. When the telescope was first turned to the stars in August, after the accident to the elevating floor had been repaired, and before the dome and floor could be actively used, it was found that an objectionable broad beam of ghostly light ran through every bright star, and that, even with good seeing, no sort of definition could be got out of the glass. It had defined well before the accident, and the beam of light had not then existed. It was feared that some injury had happened to the object-glass by the jar the telescope must have received when the floor fell, for it crashed against the pier in falling. The next day Professor HALE and the rest of us examined the big lens by daylight, and it was then seen that some spiders had gained access to the tube, or had been closed up in it when the object-glass was put on. They had woven a perfect network of webs close to the inner lens on the side towards the eye-end. It was at once suspected that these webs were responsible for the lack of definition and the beam of light — for they ran in the same direction as the beam of light. Mr. ELLERMAN climbed up inside the tube and removed the offensive webs with a dust-brush. That night the beam of light had disappeared and the definition returned.

In the following observations, the center of the disc of *Neptune* was bisected, as in previous measures. The smallness of the image makes this preferable to bisecting the limb. In the settings the wires have been placed either normal to or parallel with the eyes. Four or five settings were made for position-angle, and three to four for each double distance. The parallel was determined at the time of observation by the planet itself, from three to four settings being made. No refraction-correction has been applied, as it would be insignificant from the smallness of the distances measured. The two sets of distances on each side of the fixed wire are given, and these will give some idea of the consistency of the measures.

A value of $9''.677$ for the revolution of the micrometer-screw has been used. This will differ by a very small quantity, only, from the final value, derived from a great number of determinations. The difference is insensible in these measures.

The large number of observations, 51 in all, is rather unusual, and was made possible by the kindness of Professor HALE, who has placed the telescope at my disposal on a number of nights beside my own, and who has extended

every possible courtesy to aid in the work, as it was deemed advisable to get as continuous a set of observations as possible.

A micrometer which was kindly loaned the observatory by Dr. Lewis Swift, was used on several occasions, while the 40-inch micrometer was undergoing changes. This is indicated in the notes. A revolution of the screw of this micrometer was 3″.380.

Micrometrical Observations of the Satellite of *Neptune*.

90th Meridian Time 1897	h	m	s	Position Angle	Distance	Settings	Remarks
				°	″		
Sept. 14	14	45	53	242.48		4	Swift's micrometer
	14	56	42		16.27	4	
	15	2	6		15.78	4	
20	15	43	6	235.00		4	
	15	48	6		15.53	3	
	15	52	24		15.12	3	
22	15	15	24	93.19		4	
	15	21	4		14.81	3	
	15	24	24		14.85	3	
24	16	33	10	335.10		4	
	16	37	37		9.93	3	Fine seeing
	16	39	49		9.86	3	
26	15	0	8	230.44		4	Seeing very bad
	15	4	2		15.10	3	
	15	7	14		14.58	3	
Oct. 3	14	40	20	144.70		4	Faint
	14	47	24		10.79	3	Seeing bad
	14	52	14		10.57	3	
6	15	52	22	315.59		5	Very difficult
	15	58	11		10.99	3	Seeing very bad
	16	2	26		10.63	3	
8	14	3	50	219.83		4	Very difficult
	14	9	27		13.55	3	Seeing very bad
	14	12	50		14.38	4	
12	13	34	13	311.47		4	
	13	40	29		10.92	3	
	13	45	0		11.18	3	
14	13	34	12	213.58		4	
	13	39	56		12.54	4	
	13	42	51		12.47	4	
25	13	9	11	248.85		4	
	13	14	13		16.60	3	
	13	17	33		17.11	3	
26	12	3	28	201.90		4	
	12	7	47		11.70	3	
	12	10	23		11.72	3	
Nov. 2	13	43	23	101.75		4	
	13	49	11		13.99	3	
	13	53	3		14.38	3	

90th Meridian Time 1897–8	h	m	s	Position Angle	Distance	Settings	Remarks
				°	″		
Nov. 9	15	38	43	53.16		4	Seeing very bad
	15	45	7		15.12	3	
	15	49	13		15.38	3	
22	11	8	6	335.18		4	Very difficult
	11	15	3		10.09	3	Seeing excessively bad
	11	19	1		9.76	3	
23	11	26	38	268.56		5	
	11	34	12		15.86	4	
	11	38	17		15.49	4	
Dec. 6	15	9	30	202.00		4	Swift's micrometer
	15	16	47		12.33	3	
	15	22	6		12.45	4	
7	14	27	19	118.53		4	Swift's micrometer
	14	34	53		12.54	3	Very difficult
	14	40	43		12.43	4	Seeing very bad
20	14	44	32	60.54		5	
	14	55	3		16.33	3	
	14	58	3		15.92	3	
21	10	58	36	15.15		2	Stopped by clouds
	12	26	47	8.40		4	Satellite very difficult. Thick sky
	12	35	5		10.77	3	
	12	39	59		10.63	3	
25	10	3	38	105.31		4	
	10	12	48		13.86	3	
	10	16	58		13.83	3	
26	9	8	3	64.00		4	
	9	11	15		16.84	3	
	9	17	15		16.63	3	
27	9	26	42	7.02		4	
	9	32	4		10.83	3	
	9	35	0		11.04	3	
29	9	2	10	242.75		4	
	9	7	22		16.23	3	
	9	13	16		16.39	3	
Jan. 1	7	53	0	61.18		5	Seeing very bad
	7	58	36		16.82	3	
	8	1	20		16.14	3	
2	10	13	53	354.05		4	Fairly well seen
	10	17	49		10.24	3	
	10	20	17		10.11	3	

90th Meridian Time 1898		Position Angle	Distance	Settings	Remarks
	h m s	°	″		
Jan. 3	13 2 37	267.25		6	Faint and difficult
	13 9 35		15.87	4	
	13 14 29		15.50	4	
16	10 58 33	222.52		6	Difficult
	11 8 3		14.55	3	Seeing very bad
	11 11 21		14.27	3	
17	9 45 3	143.20		5	Faint, but observation good
	9 52 17		10.81	3	
	9 56 41		10.66	3	
18	7 41 13	85.87		4	Poorly seen
	7 52 18	84.77		4	Better seen
	8 4 47		15.43	3	
	8 7 59		16.23	3	
23	7 50 36	138.14		5	Faint
	7 57 30		10.64	4	Seeing very bad
	8 2 0		10.76	5	
27	11 4 36	252.26		5	Difficult
	11 10 24		16.61	3	Seeing very bad
	11 13 12		16.57	3	
Feb. 23	8 31 52	56.59		4	
	8 36 22		15.69	3	
	8 39 17		15.84	3	
26	7 59 51	233.37		5	Faint
	8 6 6		15.79	4	Seeing poor
	8 10 45		15.27	4	
Mar. 2	8 16 16	339.39		5	Faint
	8 21 37		9.79	3	Seeing poor
	8 24 3		10.00	3	
5	6 58 0	158.64		5	
	7 2 45		9.97	4	
	7 7 24		9.99	3	
6	6 52 54	87.68		4	
	6 56 59		15.12	3	
	6 59 17		15.36	3	
7	6 46 27	48.73		4	Seeing good. No wind. Observation good
	6 50 56		14.60	3	
	6 53 40		14.54	3	
13	6 49 29	42.30		4	Through clouds and difficult
	6 58 12		13.93	4	
	7 12 45		13.81	4	
	7 33 45	41.96		4	Cleared away and repeat obsns.
	7 36 57		14.08	3	Satellite better seen
	7 38 57		13.80	4	
Mar. 14	7 7 50	320.95		6	Very difficult
	7 20 27		9.97	5	Seeing excessively bad
	7 25 11		10.32	5	
15	7 4 26	261.07		5	Seeing very bad
	7 9 45		15.78	4	
	7 12 59		15.56	4	
19	7 5 42	37.06		5	
	7 12 25		12.94	4	
	7 15 22		12.95	4	
23	7 16 21	123.06		6	
	7 24 51		11.45	4	
	7 28 27		11.47	4	
	7 45 3	120.53		4	Satellite better seen at second set
	7 51 25		11.67	3	
	7 53 37		11.73	3	
29	7 31 3	113.67		5	
	7 35 41		12.25	3	
	7 38 23		12.11	3	
Apr. 1	8 0 7	287.34		6	
	8 6 45		12.44	3	
	8 10 15		12.29	3	
2	7 49 57	243.87		5	Sat. difficult
	7 56 48		16.48	4	
	8 0 6		16.52	4	
3	7 39 23	190.50		5	Very difficult
	7 44 55		11.09	3	Seeing very bad
	7 48 55		11.21	3	
5	7 45 39	63.34		5	Seeing good
	7 49 51		15.96	3	Satellite easy and bright
	7 51 57		16.10	3	
11	7 55 1	57.25		4	
	7 58 54		14.94	3	
	8 1 30		15.38	3	
20	8 11 25	228.35		4	
	8 16 1		14.57	3	
	8 18 31		14.43	3	
23	7 45 6	47.99		4	Very low and difficult
	7 50 6		14.09	3	
	7 53 30		13.75	3	

On Sept. 24, a 15ᴹ–16ᴹ star was seen in P.A. 40°–50° ±, and dist. 12″ ±. It was seen again on the 26th north following. On Dec. 29, 1897, an 8ᴹ star was in the field south of *Neptune*. The following measures were made of it, referred to the center of *Neptune*.

	h m s	Position Angle	Distance	Set
		°	″	
1897 Dec. 29	9 18 22	161.98	. . .	4
	9 23 16	. . .	138.35	3
	9 26 46	. . .	138.47	3

The star was of a reddish color, and by contrast, the disc of *Neptune* was greenish in tint. The time in these obsns. is $6^h\ 0^m\ 0^s$. Slow of Gr.

Besides these observations of the satellite of *Neptune*, a series of micrometer-measures has been undertaken on several of the nebulas, for parallax. The planetary nebulas are being measured, and a micrometrical survey of the globular cluster *M* 5 has been undertaken, as well as the observation of some of the variable stars of that cluster found in the Harvard College photographs.

Yerkes Observatory, Williams Bay, Wis., 1898 *May* 6.

MEASURES OF THE FIFTH SATELLITE OF *JUPITER*,

BY R. G. AITKEN.

The following measures of *Jupiter's* Fifth Satellite were made with the 36-inch refractor of the Lick Observatory, using a 350-power eyepiece. A very thin piece of smoked glass was inserted as nearly as possible in the focus of this eyepiece, cutting off about half of the field of view. In making the observations, the position-angle of *Jupiter's* belts was first determined, and the circle then set at right-angles to this reading, and clamped firmly. The nearer limb of the planet was allowed to project slightly beyond the edge of the occulting bar, and was bisected with the fixed wire; settings on the satellite were then made with the movable wire in as quick succession as possible.

In the published measures, the individual settings made within five or six minutes are combined into mean results. The columns give in order the number of independent settings, the mean time (Pacific Standard) and the mean distance of the satellite from the center of the planet. No corrections have been applied to the readings. As will be seen, the x-coordinate only was measured; under the conditions it did not seem advisable to attempt measures of the y-coordinate.

Friday, 1898 *March* 4. — *East Elongation.* The satellite was nearly at elongation at the beginning of the observations, and was seen without difficulty. A light wind, however, swayed the telescope, and made all the settings difficult and somewhat uncertain.

Position-angle of belts, 114°.4; semi-diameter of *Jupiter*, 20″.8.

	h m s	″		h m s	″
3	10 30 22	52.0	1	11 43 15	46.6
2	38 20	51.6	2	48 35	46.1
2	44 25	52.7	2	54 10	43.4
2	52 5	52.5	1	11 57 20	43.0*
4	10 59 10	53.6	3	12 13 32	37.8
3	11 6 41	52.3	3	19 25	36.1
3	14 3	52.5	3	24 42	35.3
4	22 1	51.5	1	27 5	34.3*
3	11 26 15	50.5	1	12 31 20	32.5*

* Uncertain.

Sunday, 1898 *March* 27. — *West Elongation.* The satellite was exceedingly faint, even when at elongation, and, at moments, disappeared entirely. Wind interfered with all measures after 15^h 0^m.

Position-angle of belts, 116°.0; semi-diameter of *Jupiter*, 21″.1.

	h m s	″		h m s	″
4	13 52 30	48.4	3	15 2 24	53.3
4	13 57 39	50.4	2	6 38	52.6
3	14 1 49	52.2	3	11 29	52.2
3	5 11	52.6	3	15 4	51.7
3	9 16	53.0	2	17 20	51.6
2	13 51	52.8	4	21 6	50.9
3	21 21	54.6	3	27 59	49.1
3	32 27	54.3	2	33 33	48.4
3	39 54	55.3	3	38 42	45.9
3	44 41	53.8	3	42 6	45.3
3	48 20	54.5	3	45 9	43.8
3	51 21	53.4	2	47 52	43.7*
2	14 54 6	53.7	2	15 50 54	42.1*

* Very uncertain.

Friday, 1898 *April* 8. — *West Elongation.* Satellite even fainter than on night of previous measure, and observations correspondingly difficult.

Position-angle of belts, 114°.5; semi-diameter of *Jupiter*, 21″.0.

	h m s	″		h m s	″
4	12 17 18	43.7	4	13 36 46	53.4
3	22 22	44.2	2	40 3	53.4
3	25 48	44.0	3	47 58	52.7
4	43 24	48.6	2	13 57 2	50.3
4	47 43	49.4	4	14 1 21	50.7
4	52 13	49.8	3	6 15	49.9
3	12 56 56	50.6	2	9 35	49.9
3	13 2 49	51.6	2	19 4	49.7*
4	8 36	52.3	2	21 42	45.2
2	14 17	52.9	3	29 56	40.7
4	17 37	53.2	3	34 30	36.1†
2	13 25 42	53.1	2	14 37 59	32.8†

* Uncertain. † Very uncertain.

Saturday, 1898 *April* 16. — *West Elongation.* Satellite well seen only for about half an hour at elongation. Measures difficult.

Position-angle of *Jupiter's* belts, 115°.2; semi-diameter of *Jupiter*, 20″.8.

	h m s	″		h m s	″
4	11 57 37	47.5	3	12 54 39	52.8
4	12 4 10	50.1	3	12 57 13	53.0
2	10 6	50.6	3	13 3 7	52.6
1	18 2	52.9	3	12 31	51.9
4	28 29	53.3	3	16 49	51.7
3	31 59	53.8	2	19 50	51.9
3	39 0	53.7	3	24 55	49.9
3	12 42 4	53.7	2	13 32 0	47.0*

* Uncertain.

Lick Observatory, University of California, 1898 *May* 2.

PROPER MOTION OF THE *BERLIN JAHRBUCH* STAR, GR. 1771,

BY J. G. PORTER.

The star Groombridge 1771, being No. 436 of the *Fundamental-Catalog der Astronomischen Gesellschaft*, has a motion of $-0^s.0173$ assigned to it. In using this star recently in connection with others for the determination of the clock-error, I noticed a discrepancy of nearly half a second in time. An investigation reveals the fact that the above proper motion is entirely wrong. The following table shows the authorities I have used, the systematic corrections being taken from Dr. AUWERS's tables.

	Epoch	R.A. 1900.0	Reduc.	Obs.	Epoch	Decl. 1900.0	Reduc.
		h m s				° ′ ″	
Fedorenko,	1790.2	11 16 54.88	–	1	1790.2	+64 52 38.9	–
Groombridge,	1810.3	54.69	+0.40	–	1810.3	36.8	–0.4
Rümker,	1836.	55.05	+0.01	3	1836.	37.9	–1.1
Armagh,	1842.7	55.11	0.00	6 , 5	1840.5	38.2	+0.2
Radcliffe,	1844.6	55.15	–0.01	3 , 5	1846.7	37.7	+0.7
Pulkowa,	1866.1	55.13	+0.01	6	1866.1	38.2	+0.1
Romberg,	1875.1	54.96	0.00	15 , 14	1875.1	39.2	+0.1
10-year Catal.,	1882.5	11 16 55.04	+0.04	9 , 31	1881.2	+64 52 39.0	+0.2

The small motion in declination of $+0''.027$ is confirmed, but in right-ascension the movement is evidently inappreciable. The star's right-ascension as given in the *Berlin Jahrbuch* is now therefore too small by $0^s.40$.

Cincinnati Observatory, 1898 *April* 22.

OBSERVATIONS OF MINOR PLANETS,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,

BY WILLIAM J. HUSSEY.

1897-98 Mt. Hamilton M.T.		✱	No. Comp.	Planet — ✱ $\Delta\alpha$	Planet — ✱ $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
				(387) [1894 *AZ*].					
	h m s			m s	′ ″	h m s	° ′ ″		
Dec. 30	12 38 36	1	14 , 9	+0 24.26	+6 47.3	7 38 59.01	+13 12 59.5	*n*8.629	0.553
31	11 17 35	2	8 , 8	+0 8.37	+4 5.5	7 38 11.00	+13 17 32.4	*n*9.294	0.568
Jan. 2	14 43 18	3	11 , 9	–0 27.79	–0 58.7	7 36 20.41	+13 28 7.5	9.380	0.575
3	11 0 18	3	10 , 8	–1 12.26	+3 16.6	7 35 35.96	+13 32 22.7	*n*9.310	0.569
4	12 0 19	4	10 , 8	–1 30.28	–5 30.6	7 34 40.76	+13 37 35.3	*n*8.875	0.550
12	11 4 22	5	10 , 8	–1 10.88	+0 52.6	7 27 32.09	+14 20 10.5	*n*9.037	0.540
13	10 20 3	6	8 , 8	+0 3.68	+6 6.3	7 26 39.45	+14 25 32.8	*n*9.275	0.547
14	9 44 56	7	8 , 9	+2 16.62	–3 0.7	7 25 46.61	+14 31 0.7	*n*9.445	0.576
15	12 35 40	8	10 , 8	+1 16.51	+2 24.3	7 24 46.03	+14 37 20.2	9.053	0.537
	13 5 27	7	8 , 8	+1 15.75	+3 28.0	7 24 45.75	+14 37 29.3	9.241	0.554
17	10 48 22	9	10 , 8	+1 6.62	–4 37.1	7 23 2.30	+14 48 14.8	*n*8.967	0.531
20	14 31 22	10	8 , 8	–0 12.05	+3 52.3	7 20 15.29	+15 6 22.0	9.562	0.597
				(276) *Adelheid.*					
Dec. 30	15 51 2	11	13 , 8	–0 56.63	–4 29.3	8 11 38.48	–11 31 43.3	9.437	0.803
Jan. 2	13 14 0	12	12 , 8	–0 42.18	–3 21.8	8 9 41.14	–11 40 31.7	*n*7.881	0.823
3	12 38 30	12	9 , 8	–1 23.37	–5 52.2	8 8 59.97	–11 43 2.3	*n*7.863	0.822
13	12 4 48	13	8 , 8	–0 25.88	+0 52.4	8 1 27.18	–11 53 52.8	*n*8.653	0.824
15	14 29 26	15	8 . 8	–0 3.07	–3 5.6	7 59 46.28	–11 42 37.2	9.417	0.805
				(213) *Lilaea.*					
Jan. 20	11 47 24	17	8 , 8	–0 10.82	+1 35.6	9 27 13.08	+16 58 13.3	*n*9.310	0.510
				(247) *Eukrate.*					
Jan. 12	9 1 18	18	8 , 8	–0 16.97	+0 17.3	7 43 15.99	+62 14 14.1	*n*9.973	*n*0.233
15	10 35 50	20	8 , 8	+0 4.59	–4 50.3	7 37 21.03	+61 57 43.6	*n*9.525	*n*0.555
				(354) *Eleonora.*					
Mar. 11	11 23 33	21	8 , 8	–3 14.92	+0 0.6	10 58 11.70	+19 40 53.4	*n*8.494	0.422
13	10 59 44	22	10 , 8	+0 14.61	–1 20.1	10 56 49.17	+20 1 57.9	*n*8.803	0.416
18	10 50 27	23	8 , 8	–3 24.48	+7 12.1	10 53 31.77	+20 50 33.6	*n*8.533	0.393

Mean Places for 1897–98 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	7 38 28.99	+5.76	+13 6 22.2	−10.0	Glasgow 1942
2	7 37 56.85	+5.78	+13 13 36.9	−10.0	10^M ± connected with *1
3	7 36 45.74	+2.46	+13 29 8.1	− 1.9	Göttingen 1789
4	7 36 8.54	+2.50	+13 43 8.0	− 2.1	Glasgow$_2$ 666
5	7 28 40.35	+2.62	+14 19 20.1	− 2.2	Weisse's Bessel 7^{h}803
6	7 26 33.15	+2.62	+14 19 28.6	− 2.1	Weisse's Bessel 7^{h}736
7	7 23 27.36	+2.63	+14 34 3.4	− 2.0	B.B. VI, +14°1677
8	7 23 26.88	+2.64	+14 34 58.0	− 2.1	B.B. VI, +14°1676
9	7 21 53.02	+2.66	+14 52 54.0	− 2.1	Glasgow 1869
10	7 20 24.63	+2.71	+15 2 32.0	− 2.3	Auwers, Berlin A.G. Catal. 2830
11	8 12 30.14	+4.79	−11 27 3.2	−10.8	Weisse's Bessel 8^{h}270
12	8 10 21.15	+2.17	−11 37 9.3	− 0.6	Santini 1101
13	8 1 50.72	+2.34	−11 54 42.3	− 2.9	S.DM. −11°2238. Connected with *14
14	8 2 1.22	+2.34	−12 0 49.8	− 2.9	½ (W.B. 7^{h}1768 + Santini 991)
15	7 59 46.98	+2.37	−11 39 28.2	− 3.4	S.DM. −11°2225. Connected with *16
16	7 59 54.87	+2.37	−11 44 24.3	− 3.4	Stone. Radcliffe Catal. 2058
17	9 27 21.27	+2.63	+16 56 42.7	− 5.0	Auwers, Berlin A.G. Catal. 3843
18	7 43 27.96	+5.00	+62 13 59.2	− 2.4	DM. +62°958. Connected with *19
19	7 46 28.84	+5.01	+62 18 30.0	− 2.7	Krueger, Helsingfors-Gotha A.G. Catal. 5271
20	7 37 11.43	+5.01	+62 2 35.0	− 1.1	" " " " 5204
21	11 1 23.57	+3.05	+19 41 8.5	−15.7	Auwers, Berlin A.G. Catal. 4358
22	10 56 31.49	+3.07	+20 3 33.4	−15.4	Becker, Berlin A.G. Catal. 4163
23	10 56 53.14	+3.11	+20 43 36.6	−15.1	" " " 4166

Reduction to apparent place: for *12 for Jan. 3 is $\Delta\alpha = +2^s.19$, $\Delta\delta = -0''.8$. Direct measures, comparing stars 7 and 8, give $\Delta\alpha = 0^s.72$, $\Delta\delta = 54''.7$.

Mt. Hamilton, Cal., 1898 *April* 30.

OBSERVATIONS OF (354) *ELEONORA*,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

BY E. F. CODDINGTON.

1898 Mt. Hamilton M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's Apparent α	Planet's Apparent δ	log Δp for α	log Δp for δ
h m s			m s	′ ″	h m s	° ′ ″		
Mar. 11 12 27 39	1	12 , 8	−3 16.81	+0 31.2	10 58 9.81	+19 41 24.0	9.059	0.431
13 11 14 33	2	8 , 8	+0 14.10	−1 11.9	10 56 48.66	+20 2 6.1	n8.452	0.413
18 12 23 44	3	8 , 9	−3 26.87	+7 46.6	10 53 29.38	+20 51 8.1	9.232	0.425

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	11 1 23.57	+3.05	+19 41 8.5	−15.7	Auwers, Berlin A.G. Catal. 4358
2	10 56 31.49	+3.07	+20 3 33.4	−15.4	Becker, Berlin A.G. Catal. 4163
3	10 56 53.14	+3.11	+20 43 36.6	−15.1	Becker, Berlin A.G. Catal. 4166

Mt. Hamilton, Cal., 1898 *May* 3.

OBSERVATIONS OF 4885 *Z CENTAURI* AND THE NEBULA N.G.C. 5253,

BY WILLIAM J. HUSSEY.

In *A.J.* 371 and 383, I have given estimates of the magnitudes of *Z Centauri* on certain dates in December, 1895, and January, February, June and July, 1896. Since then I have made the following observations, using the comparison-stars referred to in *A.J.* 383, particularly the stars *E* and *F*, as the basis for the estimation of magnitude. At

all times the star has been difficult on account of the nebula surrounding it. This nebula, when seen under the best conditions, has every appearance of being a part of the nebula N.G.C. 5253. Regarding it so, the latter nebula, as seen in the large telescope, may be described as having somewhat the form of the Great Nebula in *Andromeda* as seen in a very small telescope. There are, however, these important differences: — N.G.C. 5253 has a relatively stronger central condensation, and its ends are not equally bright; the south preceding end is many times brighter than the north following end in which *Z Centauri* is situated.

1897 Jan.	4	Invisible. Fainter than $16\frac{1}{2}^M$.
Apr.	1	Visible. $16\frac{1}{2}^M$, or somewhat fainter.
May	2	Seen with difficulty. $16\frac{1}{2}^M$, or fainter.
June	6	Invisible. Fainter than $16\frac{1}{2}^M$.
	27	Invisible. Seeing not very good. Faintest stars visible about 16^M.
July	4	Invisible.
Dec.	28	Invisible. Seeing not very good. Faintest stars visible about $15\frac{1}{2}^M$.
1898 Feb.	13	16^M.
Apr.	11	$16\frac{1}{2}^M$.
	12	$16\frac{1}{2}^M$. Certainly fainter than star *F*.
	21	$16\frac{1}{2}^M$, or fainter.

Mt. Hamilton, Cal., 1898 *May* 2.

EPHEMERIS OF WINNECKE'S COMET, *a* 1898,

By C. HILLEBRAND (continued from p. 16).

(*A.N.* 3482): For Berlin Midnight.

1898	α	δ	log Δ	$1:r^2\Delta^2$	1898	α	δ	log Δ	$1:r^2\Delta^2$
	h m s	° ′				h m s	° ′		
June 5.5	2 0 48	−0 52.3			June 13.5	2 18 47	−0 0.1		
7.5	5 26	38.3	0.2754	0.13	15.5	23 3	+0 11.4	0.2817	0.12
9.5	9 59	24.9			17.5	27 13	22.2		
11.5	2 14 26	−0 12.2	0.2788	0.13	19.5	2 31 17	+0 32.3	0.2841	0.11

SEARCHING EPHEMERIS FOR ENCKE'S COMET,

By A. IWANOW.

(*A.N.* 3490): For Berlin Noon.

1898	α	δ	log Δ	1898	α	δ	log Δ
	h m s	° ′			h m s	° ′	
June 1.0	6 7 12	+20 15.5	9.9496	June 25.0	7 57 38	− 7 12.1	9.5565
3.0	16 58	18 55.0	.9191	27.0	8 12 26	11 28.8	.5248
5.0	25 54	17 27.5	.8879	29.0	29 38	16 13.7	.4958
7.0	34 13	15 52.9	.8562	July 1.0	8 49 51	21 23.9	.4708
9.0	42 9	14 10.8	.8241	3.0	9 13 37	26 50.8	.4518
11.0	49 55	12 20.2	.7916	5.0	9 41 31	32 19.7	.4402
13.0	6 57 42	10 20.0	.7588	7.0	10 13 48	37 30.6	.4372
15.0	7 5 44	8 8.2	.7255	9.0	10 50 14	42 0.7	.4429
17.0	14 14	5 42.8	.6918	11.0	11 29 39	45 34.8	.4564
19.0	23 24	3 1.0	.6578	13.0	12 10 18	47 58.8	.4772
21.0	33 29	+ 0 0.2	.6237	15.0	12 49 46	49 21.5	.5025
23.0	7 44 48	− 3 23.5	9.5898	17.0	13 26 1	−49 52.2	9.5310

CORRIGENDUM.

No. 433, p. 7, col. 2, line 8, *for* 264° 54′ 34″ *read* 262° 54′ 34″.

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THEORY OF THE INFLUENCE OF A RESISTING MEDIUM UPON BODIES MOVING IN PARABOLIC ORBITS,

By F. R. MOULTON.

Very satisfactory theories of the motions of the heavenly bodies describing ellipses in resisting media have been given, but as the eccentricities of the orbits approach unity the series employed become very slowly convergent, and cease to hold altogether for parabolas. In this latter case, however, the formulas can be put in a very simple and general form.

From a practical point of view this problem is not entirely devoid of interest, as most of the comets, which on account of their enormous dimensions and small masses are most liable to have measurable disturbances from this source, move in sensibly parabolic orbits. Besides, many of them pass so near to the sun that they move with great velocities, and some have even traversed several millions of miles of the sun's corona. If the corona acts as a resisting medium upon a comet passing through it, it will be interesting to know what elements of the parabolic orbit will be changed, and how.

The differential equations of motion in LAGRANGE's second form are

$$(1)\quad \left\{\begin{aligned} \frac{dx}{dt} &= \frac{\partial(H-\Omega)}{\partial x'} \;;\quad \frac{dx'}{dt} = -\frac{\partial(H-\Omega)}{\partial x} \\ \frac{dy}{dt} &= \frac{\partial(H-\Omega)}{\partial y'} \;;\quad \frac{dy'}{dt} = -\frac{\partial(H-\Omega)}{\partial y} \\ \frac{dz}{dt} &= \frac{\partial(H-\Omega)}{\partial z'} \;;\quad \frac{dz'}{dt} = -\frac{\partial(H-\Omega)}{\partial z} \end{aligned}\right.$$

where

$$\frac{dx}{dt} = x' \;,\quad \frac{dy}{dt} = y' \;,\quad \frac{dz}{dt} = z' \;,$$

$$H = T - U \;,\quad T = \tfrac{1}{2}(x'^2+y'^2+z'^2) \;,\quad U = \frac{k^2\mu}{r} \;,$$

μ is the sum of the masses of the sun and the revolving body, k^2 is the Gaussian constant, and Ω is such a function that

$$\frac{\partial\Omega}{\partial x} \;,\quad \frac{\partial\Omega}{\partial y} \;,\quad \frac{\partial\Omega}{\partial z}$$

are the components of the disturbing force in the direction of the x, y and z axes respectively.

If Ω be supposed equal to zero in (1), and the Jacobian canonical constants of integration α_1, α_2, α_3 : β_1, β_2, β_3 be taken, we shall have the canonical elements of motion in a conic section. They have the following well-known geometrical meaning.

$$\left.\begin{aligned} \alpha_1 &= \frac{k^2(e^2-1)}{2p} &;\quad \beta_1 &= -T \\ \alpha_2 &= k\sqrt{p}\cos i &;\quad \beta_2 &= \Omega \\ \alpha_3 &= k\sqrt{p} &;\quad \beta_3 &= \pi-\Omega \end{aligned}\right\} \qquad (2)$$

where e is the eccentricity; p, the parameter; i, the inclination of the plane of the orbit to the plane of the ecliptic; T, the time of perihelion passage; Ω, the longitude of the ascending node; π, the longitude of the perihelion. If the mass of the revolving body is negligible, $\mu = 1$.

Considering now the disturbing force Ω, we have by the method of variation of parameters as shown by JACOBI in Chapter XXXVI of his *Vorlesungen über Dynamik*,

$$\left.\begin{aligned} \frac{d\alpha_1}{dt} &= \frac{\partial\Omega}{\partial\beta_1} \;;\quad \frac{d\beta_1}{dt} = -\frac{\partial\Omega}{\partial\alpha_1} \\ \frac{d\alpha_2}{dt} &= \frac{\partial\Omega}{\partial\beta_2} \;;\quad \frac{d\beta_2}{dt} = -\frac{\partial\Omega}{\partial\alpha_2} \\ \frac{d\alpha_3}{dt} &= \frac{\partial\Omega}{\partial\beta_3} \;;\quad \frac{d\beta_3}{dt} = -\frac{\partial\Omega}{\partial\alpha_3} \end{aligned}\right\} \qquad (3)$$

It is manifestly impossible to find the perturbations of the major axis in the case of a parabolic orbit, so we shall use as elements, p, e, π, T, i and Ω.

We find from (2),

$$\left.\begin{aligned} p &= \frac{\alpha_3^2}{k^2} &;\quad T &= -\beta_1 \\ e^2 &= 1+\frac{2\alpha_1\alpha_3^2}{k^4} &;\quad \cos i &= \frac{\alpha_2}{\alpha_3} \\ \pi &= \beta_2+\beta_3 &;\quad \Omega &= \beta_2 \end{aligned}\right\} \qquad (4)$$

Differentiating (4) and letting $\alpha_1 = 0$ and $e = 1$ as they become in a parabolic orbit, we have

$$(5)\begin{cases} \dfrac{dp}{dt} = \dfrac{2\alpha_3}{k^2}\dfrac{d\alpha_3}{dt} & ; \quad \dfrac{dT}{dt} = -\dfrac{d\beta_1}{dt} \\ \dfrac{de}{dt} = \dfrac{\alpha_3^2}{k^4}\dfrac{d\alpha_1}{dt} & ; \quad \sin i\dfrac{di}{dt} = \dfrac{\alpha_2\dfrac{d\alpha_3}{dt} - \alpha_3\dfrac{d\alpha_2}{dt}}{\alpha_3^2} \\ \dfrac{d\pi}{dt} = \dfrac{d\beta_2}{dt} + \dfrac{d\beta_3}{dt} & ; \quad \dfrac{d\Omega}{dt} = \dfrac{d\beta_2}{dt} \end{cases}$$

Substituting in (5) the values of the canonical elements and their derivatives obtained from (2) and (3), we have

$$(6)\begin{cases} \dfrac{dp}{dt} = \dfrac{2}{k}\sqrt{p}\dfrac{\partial\Omega}{\partial\beta_3} ; & \dfrac{dT}{dt} = \dfrac{\partial\Omega}{\partial\alpha_1} \\ \dfrac{de}{dt} = \dfrac{p}{k^2}\dfrac{\partial\Omega}{\partial\beta_1} ; & \dfrac{di}{dt} = \dfrac{csc\, i}{k\sqrt{p}}\left(\cos i\dfrac{\partial\Omega}{\partial\beta_3} - \dfrac{\partial\Omega}{\partial\beta_2}\right) \\ \dfrac{d\pi}{dt} = -\dfrac{\partial\Omega}{\partial\alpha_2} - \dfrac{\partial\Omega}{\partial\alpha_3} ; & \dfrac{d\Omega}{dt} = -\dfrac{\partial\Omega}{\partial\alpha_2} \end{cases}$$

In the case of the action of a resisting medium the perturbative force is a function of the coördinates alone as it is in the mutual actions of the planets, for, although the resistance in a given medium depends upon the velocity of the moving body, in the present case the velocities are directly functions of the coördinates. Hence if $j = 1, 2, 3$ and σ_j represents either α_j or β_j we have

$$\frac{\partial\Omega}{\partial\sigma_j} = \frac{\partial\Omega}{\partial p}\frac{\partial p}{\partial\sigma_j} + \frac{\partial\Omega}{\partial e}\frac{\partial e}{\partial\sigma_j} + \frac{\partial\Omega}{\partial\pi}\frac{\partial\pi}{\partial\sigma_j} + \frac{\partial\Omega}{\partial T}\frac{\partial T}{\partial\sigma_j} + \frac{\partial\Omega}{\partial i}\frac{\partial i}{\partial\sigma_j} + \frac{\partial\Omega}{\partial\Omega}\frac{\partial\Omega}{\partial\sigma_j}$$

Carrying out the computation in detail we find from (4)

$$(7)\begin{cases} \dfrac{\partial\Omega}{\partial\alpha_1} = \dfrac{\alpha_3^2}{k^4}\dfrac{\partial\Omega}{\partial e} & ; \quad \dfrac{\partial\Omega}{\partial\beta_1} = -\dfrac{\partial\Omega}{\partial T} \\ \dfrac{\partial\Omega}{\partial\alpha_2} = -\dfrac{csc\, i}{\alpha_3}\dfrac{\partial\Omega}{\partial i} & ; \quad \dfrac{\partial\Omega}{\partial\beta_2} = \dfrac{\partial\Omega}{\partial\pi} + \dfrac{\partial\Omega}{\partial\Omega} \\ \dfrac{\partial\Omega}{\partial\alpha_3} = \dfrac{2\alpha_3}{k^2}\dfrac{\partial\Omega}{\partial p} + \dfrac{\alpha_2 csc\, i}{\alpha_3^2}\dfrac{\partial\Omega}{\partial i} & ; \quad \dfrac{\partial\Omega}{\partial\beta_3} = \dfrac{\partial\Omega}{\partial\pi} \end{cases}$$

Substituting these values in (6), and reducing by (2), we obtain

$$(8)\begin{cases} \dfrac{dp}{dt} = \dfrac{2\sqrt{p}}{k}\dfrac{\partial\Omega}{\partial\pi} ; & \dfrac{dT}{dt} = \dfrac{p}{k^2}\dfrac{\partial\Omega}{\partial e} \\ \dfrac{de}{dt} = -\dfrac{p}{k^2}\dfrac{\partial\Omega}{\partial T} ; & \dfrac{di}{dt} = -\dfrac{1}{k\sqrt{p}}\left(\tan\tfrac{i}{2}\dfrac{\partial\Omega}{\partial\pi} + csc\, i\dfrac{\partial\Omega}{\partial\Omega}\right) \\ \dfrac{d\pi}{dt} = \dfrac{\tan\frac{i}{2}}{k\sqrt{p}}\dfrac{\partial\Omega}{\partial i} - \dfrac{2\sqrt{p}}{k}\dfrac{\partial\Omega}{\partial p} ; & \dfrac{d\Omega}{dt} = \dfrac{csc\, i}{k\sqrt{p}}\dfrac{\partial\Omega}{\partial i} \end{cases}$$

These are the general formulas for the variation of parabolic elements, and can be applied numerically when Ω can be developed in terms of the elements and the time. When the perturbations arise from the action of a resisting medium the formulas take a very simple form by resolving the disturbing force into three rectangular components. Let us still keep the formulas general, and not specialize in regard to the nature of the disturbing force.

Let L be the component of the disturbing force in the direction of the radius-vector, positive when directed from the sun; M, the component perpendicular to the radius-vector and positive in the direction of motion; N, the component perpendicular to the plane of the orbit and positive toward the north. Let v be the true anomaly, and u the argument of the latitude; that is, $u = \pi - \Omega + v$. Taking rectangular axes with the origin at the sun's center, we obtain by solving the spherical triangle $x\,\Omega\,r$ the following well-known formulas,

$$(9)\begin{cases} \dfrac{\partial\Omega}{\partial x} = L(\cos u\cos\Omega - \sin u\sin\Omega\cos i) \\ \qquad + M(-\sin u\cos\Omega - \cos u\sin\Omega\cos i) \\ \qquad + N\sin\Omega\sin i \\ \dfrac{\partial\Omega}{\partial y} = L(\cos u\sin\Omega + \sin u\cos\Omega\cos i) \\ \qquad + M(-\sin u\sin\Omega + \cos u\cos\Omega\cos i) \\ \qquad - N\cos\Omega\sin i \\ \dfrac{\partial\Omega}{\partial z} = L\sin u\sin i + M\cos u\sin i + N\cos i \end{cases}$$

From the same triangle we find also

$$(10)\begin{cases} x = r(\cos u\cos\Omega - \sin u\sin\Omega\cos i) \\ y = r(\cos u\sin\Omega + \sin u\cos\Omega\cos i) \\ z = r\sin u\sin i \end{cases}$$

From the law of areas we have $r^2\dfrac{dv}{dt} = k\sqrt{p}$. Letting $w = \tan\frac{v}{2}$ this becomes

$$\frac{k(1+e)^2\,dt}{2p^{3/2}} = \frac{(1+w^2)\,dw}{(1+\frac{1-e}{1+e}w^2)^2}$$

Letting $\frac{1-e}{1+e} = \lambda$ and expanding in powers of λ we find after integration,

$$(11)\quad \frac{k(1+e)^2(t-T)}{2p^{3/2}} = w + \frac{w^3}{3} - 2\lambda\left(\frac{w^3}{3} + \frac{w^5}{5}\right) + 3\lambda^2\left(\frac{w^5}{5} + \frac{w^7}{7}\right) - \ldots\ldots$$

In the case of the parabola $e = 1$ and $\lambda = 0$ so (11) becomes

$$(12)\begin{cases} \dfrac{2k(t-T)}{p^{3/2}} = \tan\frac{v}{2} + \frac{1}{3}\tan^3\frac{v}{2}. \quad \text{We have also,} \\ r = \dfrac{p}{1+e\cos v} \\ u = \pi - \Omega + v \end{cases}$$

Letting σ represent any one of the elements we have

$$\frac{\partial\Omega}{\partial\sigma} = \frac{\partial\Omega}{\partial x}\frac{\partial x}{\partial\sigma} + \frac{\partial\Omega}{\partial y}\frac{\partial y}{\partial\sigma} + \frac{\partial\Omega}{\partial z}\frac{\partial z}{\partial\sigma}.$$

$\dfrac{\partial\Omega}{\partial x}$, $\dfrac{\partial\Omega}{\partial y}$ and $\dfrac{\partial\Omega}{\partial z}$ are obtained from (9) directly. We must now compute $\dfrac{\partial x}{\partial\sigma}$, $\dfrac{\partial y}{\partial\sigma}$ and $\dfrac{\partial z}{\partial\sigma}$ for each of the elements. If we let $\left(\dfrac{\partial r}{\partial\sigma}\right)$, with the parenthesis, represent

the derivative of r with respect to σ so far as it enters explicitly we shall have the general expression,

$$\frac{\partial x}{\partial\sigma} = \frac{\partial x}{\partial r}\left\{\left(\frac{\partial r}{\partial\sigma}\right) + \frac{\partial r}{\partial v}\frac{\partial v}{\partial\sigma}\right\} + \frac{\partial x}{\partial u}\frac{\partial u}{\partial v}\frac{\partial v}{\partial\sigma} + \frac{\partial x}{\partial\sigma}$$

and similar formulas in y and z.

From (11) and (12) we find the following relations, letting $e = 1$,

$$(13)\quad \left\{\begin{aligned}
\left(\frac{\partial r}{\partial p}\right) &= \tfrac{1}{2}\sec^2\tfrac{v}{2} \\
\frac{\partial r}{\partial v} &= \tfrac{p}{2}\sec^2\tfrac{v}{2}\tan\tfrac{v}{2} \\
\frac{\partial u}{\partial v} &= 1 \\
\frac{\partial v}{\partial p} &= -\frac{\tan^3\frac{v}{2}+3\tan\frac{v}{2}}{p\sec^4\frac{v}{2}} \\
\frac{\partial v}{\partial e} &= \frac{\partial v}{\partial w}\frac{\partial w}{\partial e} \\
\frac{\partial v}{\partial w} &= 2\cos^2\tfrac{v}{2} \\
\frac{\partial w}{\partial e} &= \tfrac{1}{2}\sin v\,(1-\tfrac{1}{5}\tan^4\tfrac{v}{2})
\end{aligned}\right.$$

The other expressions required in computing

$$\frac{\partial x}{\partial\sigma},\quad \frac{\partial y}{\partial\sigma}\quad\text{and}\quad\frac{\partial z}{\partial\sigma}$$

are readily found. Carrying out the computations from (9), (10), (11), (12) and (13) we obtain

$$(14)\quad \left\{\begin{aligned}
\frac{\partial\Omega}{\partial p} &= \tfrac{1}{2}\cos v\,L - \tan\tfrac{v}{2}(1+\tfrac{1}{2}\cos v)\,M \\
\frac{\partial\Omega}{\partial e} &= p\{-\tfrac{1}{4}\cos v\sec^4\tfrac{v}{2}+\sin^2\tfrac{v}{2}(1-\tfrac{1}{5}\tan^4\tfrac{v}{2})\}\,L \\
&\quad + \tfrac{p}{2}\sin v\,(1-\tfrac{1}{5}\tan^4\tfrac{v}{2})\,M \\
\frac{\partial\Omega}{\partial\pi} &= \tfrac{p}{2}\sec^2\tfrac{v}{2}\,M \\
\frac{\partial\Omega}{\partial T} &= -\frac{k}{\sqrt{p}}\sin v\,L - \frac{2k}{\sqrt{p}}\cos^2\tfrac{v}{2}\,M \\
\frac{\partial\Omega}{\partial i} &= \tfrac{p}{2}\sin u\sec^2\tfrac{v}{2}\,N \\
\frac{\partial\Omega}{\partial\Omega} &= -p\sec^2\tfrac{v}{2}\sin^2\tfrac{i}{2}\,M - \tfrac{p}{2}\sec^2\tfrac{v}{2}\sin i\cos u\,N
\end{aligned}\right.$$

Substituting these values in (8) we have

$$(15)\quad \left\{\begin{aligned}
\frac{dp}{dt} &= \frac{p^{3/2}}{k}\sec^2\tfrac{v}{2}\,M \\
\frac{de}{dt} &= \frac{\sqrt{p}}{k}\sin v\,L + \frac{2\sqrt{p}}{k}\cos^2\tfrac{v}{2}\,M \\
\frac{d\pi}{dt} &= -\frac{\sqrt{p}}{k}\cos v\,L + \frac{\sqrt{p}}{k}\tan\tfrac{v}{2}(2+\cos v)\,M \\
&\qquad + \frac{\sqrt{p}}{2k}\tan\tfrac{i}{2}\sin u\sec^2\tfrac{v}{2}\,N \\
\frac{dT}{dt} &= \frac{p^2}{k^2}\left\{-\tfrac{1}{4}\cos v\sec^4\tfrac{v}{2}+\sin^2\tfrac{v}{2}(1-\tfrac{1}{5}\tan^4\tfrac{v}{2})\right\}L \\
&\qquad + \frac{p^2}{2k^2}\sin v\,(1-\tfrac{1}{5}\tan^4\tfrac{v}{2})\,M \\
\frac{di}{dt} &= \frac{\sqrt{p}}{2k}\cos u\sec^2\tfrac{v}{2}\,N \\
\frac{d\Omega}{dt} &= \frac{\sqrt{p}}{2k}\csc i\sin u\sec^2\tfrac{v}{2}\,N
\end{aligned}\right.$$

These formulas are general for any case where the disturbing force is a function of the coordinates, and are convenient when it is necessary to employ mechanical quadratures in the integration. When the disturbing force is the result of a resisting medium we may suppose that it acts along the tangent opposite to the direction of motion. In this case $N = 0$, and i and Ω are not changed, as is also evident from geometrical considerations.

If we denote the resisting force by R, we readily find

$$\left.\begin{aligned}
L &= -\sin\tfrac{v}{2}\,R \\
M &= -\cos\tfrac{v}{2}\,R
\end{aligned}\right\}\quad(16)$$

Substituting these expressions for L and M in (15) we obtain

$$\left.\begin{aligned}
\frac{dp}{dt} &= -\frac{p^{3/2}}{k}\sec\tfrac{v}{2}\,R \\
\frac{de}{dt} &= -\frac{2\sqrt{p}}{k}\cos\tfrac{v}{2}\,R \\
\frac{d\pi}{dt} &= -\frac{2\sqrt{p}}{k}\sin\tfrac{v}{2}\,R \\
\frac{dT}{dt} &= -\frac{p^2}{k^2}\sin\tfrac{v}{2}(\tfrac{3}{4}+\tfrac{1}{20}\tan^4\tfrac{v}{2})\,R
\end{aligned}\right\}\quad(17)$$

Since R is a positive quantity these formulas lead to the following theorems:

(*a*) *A resistance in any part of the orbit decreases the parameter.*

(*b*) *A resistance in any part of the orbit decreases the eccentricity.*

(*c*) *A resistance while* $-180° < v < 0$ *increases the longitude of the perihelion, and while* $0 < v < 180°$ *decreases it.*

(*d*) *A resistance while* $-180° < v < 0$ *makes the perihelion passage later, and while* $0 < v < 180°$ *makes it earlier.*

In effecting the integration of (17) it will be convenent to change the independent variable to v. From

$$r^2\frac{dv}{dt} = k\sqrt{p}$$

we have

$$dt = \frac{p^{3/2}}{4k}\sec^4\tfrac{v}{2}\,dv$$

Then (17) becomes

$$\left.\begin{aligned}
\frac{dp}{dv} &= -\frac{p^3}{4k^2}\sec^5\tfrac{v}{2}\,R \\
\frac{de}{dv} &= -\frac{p^2}{2k^2}\sec^3\tfrac{v}{2}\,R \\
\frac{d\pi}{dv} &= -\frac{p^2}{2k^2}\sin\tfrac{v}{2}\sec^4\tfrac{v}{2}\,R \\
\frac{dT}{dv} &= -\frac{3p^{7/2}}{16k^3}\sin\tfrac{v}{2}\sec^4\tfrac{v}{2}\,R - \frac{p^{7/2}}{80k^3}\sin^5\tfrac{v}{2}\sec^5\tfrac{v}{2}\,R
\end{aligned}\right\}\quad(18)$$

In order to carry out the integration it is necessary to have an explicit form for R. We shall certainly be very

near the truth if we assume that R is some function of the velocity of the moving body and some other function of the density of the resisting medium. Let ρ be the density of the resisting medium, V the velocity of the moving body, and h a constant to be determined by observation. Then we may write

$$(19) \qquad R = h\,F(V)\,\psi(\rho)$$

We may safely assume for $F(V)$ the very general expression

$$(20) \qquad F(V) = a_1 V + a_2 V^2 + a_3 V^3 + \ldots = \Sigma a_n V^n$$

But in parabolic motion $V^2 = \dfrac{2k^2}{r}$ hence (20) becomes

$$(21) \quad \begin{cases} F(V) = \dfrac{a_1'}{\sqrt{r}} + \dfrac{a_2'}{\sqrt{r^2}} + \dfrac{a_3'}{\sqrt{r^3}} + \ldots = \Sigma \dfrac{a'_n}{\sqrt{r^n}} \\ a'_n = a_n 2^{\frac{n}{2}} k^n \end{cases}$$

We may assume that the density of the medium decreases as the distance from the sun increases, and that R decreases as ρ decreases. We may take the very general expression fulfilling these conditions,

$$(22) \qquad \psi(\rho) = \varphi(r) = b_0 + \frac{b_1}{r} + \frac{b_2}{r^2} + \ldots = \Sigma \frac{b_n}{r^n}$$

From (19), (21) and (22) we find

$$(23) \quad R = h\left\{\frac{c_1}{\sqrt{r}} + \frac{c_2}{\sqrt{r^2}} + \frac{c_3}{\sqrt{r^3}} + \ldots\right\} = h\,\Sigma \frac{c_n}{\sqrt{r^n}}$$
$$c_n = b_0 a'_n + b_1 a'_{n-2} + b_2 a'_{n-4} + \ldots$$

From the polar equation of the parabola we have

$$\frac{1}{\sqrt{r^n}} = \frac{2^{\frac{n}{2}}}{p^{\frac{n}{2}}} \cos^n \tfrac{v}{2}$$

Hence (23) becomes

$$(24) \quad \begin{cases} R = h\,\Sigma d_n \cos^n \tfrac{v}{2} \\ d_n = \dfrac{2^{\frac{n}{2}}}{p^{\frac{n}{2}}}\, c_n \end{cases}$$

Substituting in (18) we find

$$(25) \quad \begin{cases} \dfrac{dp}{dv} = -\dfrac{p^3}{4k^2}\, h\,\Sigma d_n \cos^{n-5} \tfrac{v}{2} \\ \dfrac{de}{dv} = -\dfrac{p^2}{2k^2}\, h\,\Sigma d_n \cos^{n-3} \tfrac{v}{2} \\ \dfrac{d\pi}{dv} = -\dfrac{p^2}{2k^2}\, h\,\Sigma d_n \sin \tfrac{v}{2} \cos^{n-4} \tfrac{v}{2} \\ \dfrac{dT}{dv} = \tfrac{3}{5}\,\dfrac{p^{3/2}}{k}\,\dfrac{d\pi}{dv} - \dfrac{p^{7/2}}{80k^3}\, h\,\Sigma d_n \sin^5 \tfrac{v}{2} \cos^{n-8} \tfrac{v}{2} \end{cases}$$

Since we have agreed to suppose that the density of the medium depends upon the distance from the sun alone we have the additional theorems from (18) or (25),

(*e*) *p and e will be secularly decreased.*

(*f*) *π and T will have the same values at equal distances before and after perihelion passage.*

Equations (25) are immediately integrable and furnish the complete solution of the problem for perturbations of the first order. If the sun's corona acts upon the comets which pass through it in the manner assumed in the derivation of the equations above, it follows from (*e*) and (*f*) that all the elements except p and e will be the same before the disturbance as after it. Since these two elements are both decreased, the orbit will be changed from a parabola to an ellipse. Although it is very probable that the corona is not arranged in perfectly uniform concentric layers around the sun, yet it is reasonable to believe that such a distribution of mass represents approximately the actual condition of things, and that the errors introduced by our assumptions will be small quantities of the second order.

A numerical application of the formulas will doubtless be of interest. It will be necessary to make some assumption in regard to the form of the expression for R, and the results we arrive at must be regarded as possessing only some degree of probability. Yet we can obtain an idea of the order of a disturbance which the resistance cannot have exceeded in the case of comets thus far observed. For this purpose let us apply our formulas to the orbit of the great comet of 1882, which, passing within 300,000 miles of the sun's surface, traversed several millions of miles of the corona.

This comet was observed both before and after perihelion passage, and for such a long period that the elements of its orbit have been determined with a high degree of accuracy. Thirty-four* computations by sixteen different astronomers have led to results showing very close agreement. Gautier published two parabolic orbits and one elliptical, based on measures made before perihelion passage. Those of his elements which would not be changed by the action of a resisting medium, agree in a remarkable manner with the elliptical elements obtained by Kreutz from an elaborate discussion of all published observations. The only differences are that the perihelion points of the orbits of Kreutz are a little in advance of those found by Gautier. In all the orbits obtained by Kreutz the eccentricity is a little less than unity, but the variations in the elements found by the two computers are so slight that they could easily be accounted for by errors of observation, and we are not warranted in asserting positively that any of the elements have actually changed.

Let us suppose, however, that before perihelion passage the orbit was strictly a parabola, which was reduced by the action of the sun's corona to the ellipse found by Kreutz. From the orbits of Gautier we know that the eccentricity before perihelion passage could not have surpassed unity sensibly, hence, in making this assumption we shall find the maximum resistance compatible with the observations.

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* Galle, *Cometen Bahnen*, p. 124.

The disrupted condition of the nucleus after perihelion passage, indicates that the comet passed through a violent disturbance of some sort, and remembering the enormous velocity with which it moved, it is certainly not unthinkable that it may have arisen from collisions with material in the neighborhood of the sun. KREUTZ* found for the eccentricity of the orbit of the second of the different nuclei 0.9999080, hence, under our assumption that the orbit was at first parabolic, the variation in e is, $\delta e = -0.0000920$. In order to find the constant h, of (19), let us assume that $F(V) = V^2$ and $\psi(\rho) = \frac{1}{r^2}$. Then we have

$$(26) \qquad R = h\frac{V^2}{r^2} = \frac{2hk^2}{q^3}\cos^6\tfrac{v}{2} = \frac{2hk^2}{r^3}$$

Substituting this expression for R in the second of (18) we have

$$(27) \qquad \delta e = -\frac{4h}{q}\int\cos^3\tfrac{v}{2}\,dv = -0.0000920$$

The limits of the integral must be such that the integration shall cover the whole period during which the comet was in the corona. We shall integrate from $-\pi$ to $+\pi$, which are the logical limits after having assumed that $\psi(\rho) = \frac{1}{r^2}$, but our results would be almost exactly the same numerically if we took as limits, values of v such that $r = 10{,}000{,}000$ miles, beyond which the corona has not been observed. Let F represent the sun's attraction, that is $F = \frac{k^2}{r^2}$ when r is expressed in astronomical units. Then we have

$$(28) \qquad \frac{R}{F} = \frac{2h}{r}$$

h can easily be determined numerically from (27) since all the other quantities involved are known. Finding h, and carrying out the computation in (28) for $r = q$, or when the comet is in perihelion, we find for the ratio of resistance to attraction at that point

$$(29) \qquad \frac{R}{F} = 0.00002$$

From KREUTZ's elements we have taken

$$\log q = 7.8894539$$

The ratio $\frac{R}{F}$ would have been a little larger if we had assumed higher powers of V and r in $F(V)$ and $\psi(\rho)$, but the order of the magnitude would have remained the same. This has been verified by actual computation, and from it we may conclude that the order of the ratio would have remained the same if we had known the constants involved in the general formula (24). It is understood that by saying the order remains the same we mean that the variation will not be more than perhaps twenty times the number involved.

The acceleration of a body under the sun's attraction at the comet's perihelion distance is about 800 feet per second, hence the acceleration due to the relative motion of the comet and corona is, $R = 0.00002 \times 800 =$ one-fifth of an inch per second. This number seems to indicate the remarkable rarity of the corona at 300,000 miles from the sun's surface, even as compared to the density of the nucleus of the comet. In recapitulation of the method of obtaining this number, it may be said that it is perfectly certain that the comet passed through several millions of miles of the corona; that we took the maximum variation of the eccentricity that could have arisen from its action; and that the number above represents the order of the disturbance which cannot have been exceeded.

In order to solve the more delicate problem of finding the relative density of the corona and nucleus, let us suppose that the nucleus is a solid body equal in mass to a cylinder, with the same diameter and 6,000 miles long. (This is probably somewhere near the size of the nucleus of the comet.) As this cylinder moved through perihelion at the rate of 300 miles per second, it encountered enough material to retard it one-fifth of an inch per second. That is, we may suppose that the impact of 300 miles of the corona with a velocity of 300 miles per second, gave a cylinder of cometary matter 6,000 miles long, an acceleration of one-fifth of an inch per second. From this we infer, considering the impact alone, that the nucleus of the comet was 1,750,000 times as dense as the corona at a distance of 300,000 miles from the sun's surface. This number is subject to very large error, and about the only conclusion that we can draw is that the corona is extremely rare at that distance from the sun, or that it possesses properties quite different from those of ordinary matter.

The resistance seems to have been in this case so excessively small that it might be supposed that "electrical repulsion" could be more potent in changing the elements of the orbit, or that possibly it might offset the effect of a resisting medium. The qualitative effects of a repulsion are very easily determined. It will act in the direction of the radius vector outward, hence in (15) L will be a positive quantity and M and N each zero. Then it is evident from (15) also that, p, i and Ω *will not be changed*: e *will be decreased before perihelion and increased equally after it*: π *will be decreased while* $-\frac{\pi}{2} < v < \frac{\pi}{2}$ *and increased the rest of the time*; T *will increase part of the time and decrease the remainder.* Comparing these results with the theorems (a) .... (f) previously obtained, it is plain that in looking for evidence of the action of a resisting medium upon parabolic orbits, the "electrical repulsion" need not

*GALLE, *Cometen Bahnen*, p. 127.

be considered, even though its effects upon the elements might become sensible.

If the sun were oblate and the comet were moving in the plane of its equator, L would be a negative quantity and M and N each zero. As before, this would not mask the effects of a resisting medium. If however, the perihelion point were unsymmetrically situated with respect to the equatorial bulge, the values of L and M would not be the same for equal positive and negative values of e, and a permanent change in e might be produced. If this disturbance were large and its exact amount unknown it might lead to erroneous conclusions, but it is certainly very small. Other causes of disturbance can be treated in a similar manner.

The University of Chicago, 1898 *May*.

OBSERVATIONS OF COMET 1897 III,

MADE AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,

BY C. D. PERRINE.

1897 Mt. Hamilton M.T.	✻	No. Comp.	☌–✻ Δα	☌–✻ Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Oct. 24 9 9 6	1	d10 , 9	−2 17.90	+1 2.3	2 3 13.04	+78 14 56.1	n0.168	n0.625
12 45 21	2	. . .	−0 1.82	−1 56.5	1 59 42.78	+78 26 25.7	9.795	n0.742
13 50 36	2	d10 , 8	−1 4.49	+1 15.5	1 58 40.11	+78 29 37.7	0.097	n0.680
27 8 17 17	3	d10 , 8	+0 20.63	−7 46.2	0 34 55.30	+81 0 49.8	n0.143	n0.728
28 14 22 44	5	d10 , 8	−0 47.41	+0 51.3	23 44 51.29	+81 34 31.8	0.490	n9.857
29 7 46 27	6	d10 , 8	−1 14.36	−3 55.8	23 14 21.33	+81 42 12.9	n9.874	n0.780
30 9 54 40	7	d10 , 8	−0 31.21	−2 8.2	22 28 38.86	+81 36 5.2	0.220	n0.711
31 14 16 25	8	10 , 6	−8 52.68	−6 41.3	21 43 7.07	+81 8 3.2	0.456	0.492
Nov. 12 7 12 11	9	d 8 , 8	+0 8.34	+5 27.4	18 47 29.14	+69 56 16.3	0.068	n0.204
15 7 37 58	11	d10 , 8	+0 1.04	−0 21.3	18 35 24.96	+67 2 25.1	0.056	n8.778

Mean Places for 1897.0 of Comparison-Stars.

✻	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	2 5 19.16	+11.78	+78 13 30.3	+23.5	DM. +78°74, Tucker L.O. Meridian Circle
2	1 59 32.83	+11.77	+78 27 58.0	+24.2	DM. +78°70 " " " "
3	0 31 24.72	+ 9.96	+81 8 3.5	+32.5	Micometer-comparison with ✻4
4	0 34 51.36	+10.05	+81 13 31.8	+32.4	Carrington 83
5	23 45 31.71	+ 6.99	+81 33 8.1	+35.4	" 3668
6	23 15 30.75	+ 4.94	+81 45 31.4	+37.3	" 3580
7	22 29 8.64	+ 1.43	+81 37 37.0	+36.4	" 3459
8	21 52 0.82	− 1.07	+81 14 8.9	+35.6	" 3348
9	18 47 24.06	− 3.26	+69 50 33.0	+15.9	Micrometer-comparison with ✻10
10	18 44 5.03	− 3.30	+69 49 20.0	+15.4	½ (Christiania 2900+Dorpat) A.G.
11	18 35 20.55	− 2.63	+67 2 32.7	+13.7	Micrometer-comparison with ✻12
12	18 36 54.36	− 2.62	+67 3 29.1	+13.8	Christiania A.G. Catal. 2881

NOTES.

d indicates that $\Delta\alpha$ was measured directly with the micrometer. The second observation of Oct. 24 was obtained from 8 measures of position-angle, and 10 measures of distance.

The second and third observations of Oct. 24, and that of Nov. 15, were made with the 36-inch refractor, power 270; all the others were made with the 12-inch refractor, power of about 150. On Nov. 7 I looked carefully for the comet with the 36-inch telescope, but failed to see anything of it owing to the moonlight, although I swept over 1° in Declination, and 13ᵐ in R.A. — Oct. 17; with the 36-inch telescope and power of 520, the comet showed a tail over 3′ long, and a stellar nucleus fully as bright as 12ᴹ, and very distinct. A long, narrow, central streamer was to be seen in the tail. On Oct. 24, the tail was estimated to be 5′ long. — Oct. 27; comet fainter than on Oct. 24; probably some haze in air. — Oct. 28; comet faint, and not easy. Condensation in head more distinct than last night.— Oct. 29; comet very diffuse and not easy to observe accurately, as there is no well-defined nucleus. Seeing 4. — Oct. 30; Tail appears longer than last night, and very straight. No well-defined head, and no nucleus. — Oct. 31; 36-inch telescope, power 270. No condensation in head, no nucleus. Tail 5′ long, and is simply a long, narrow strip of nebulosity, about same width throughout the entire length. — Nov. 12; comet very diffuse and hard to measure. Comet 7′ or 8′ long, no nucleus. — Nov. 15; 36-inch telescope, power 270. Comet faint, especially the head. The most marked condensation is in the tail, about 2′ back of the relative position of the head and nucleus. Three stars near the head of the comet which may have influenced the measures somewhat.

POSITION-ANGLE OF TAIL.

		h	m		°
Oct. 17	about	10		P.St.T.	209.3
24		14	9	"	177.5
27		9	4	"	158.5
28		14	27	"	144.4
29		7	53	"	132.6
30		9	57	"	124.9
31		14	33	"	108.0
Nov. 12		7	30		70.5
15		7	55		63.0

Mt. Hamilton, Cal., 1898 *May* 13.

OBSERVATIONS OF VARIABLE STARS — No. 7,

BY WM. E. SPERRA.

103. *T Andromedae.*

Eleven observations of this star, between 1897 Dec. 7 and 1898 Feb. 6, give as the date of maximum 1898 Jan. 4, at $7^M.6$. The brightness was $9^M.0$ at beginning, and $8^M.6$ at ending of the series of observations.

1623. *T Camelopardalis.*

A maximum of $8^M.7$ is indicated for 1897 Dec. 22 from a series of fifteen observations, extending from 1897 Oct. 3 to 1898 March 9. The rise from 10^M to 9^M was accomplished by the end of October, and from this latter date to the date of maximum the increase was $0^M.3$ only. After a short lingering following maximum the fall to 10^M was gradual.

7085. *RT Cygni.*

Seven observations, between 1897 Dec. 24 and 1898 March 29, yield as the date of maximum, 1898 Feb. 3, at $7^M.2$. The magnitudes at first and last observations were respectively $9^M.6$ and $8^M.6$.

6636. *U Sagittarii.*

This star was observed thirty-two times, between 1897 Aug. 19 and Oct. 27, with results as follows:

Maxima	Obs.	Minima	Obs.
1897 Aug. 28.64	3	1897 Aug. 19.92	3
Sept. 10.93	2	25.86	2
17.81	3	Sept. 2.40	2
Oct. 14.89	3	14.91	2
		28.89	4
		Oct. 25.81	5

7124. *η Aquilae.*

Thirty-four observations of this star, between 1897 Aug. 18 and Nov. 3, give results as follows:

Maxima	Obs.	Minima	Obs.
1897 Aug. 17.31	4	1897 Aug. 28.15	3
29.16	3	Sept. 19.37	2
Sept. 13.02	2	Oct. 17.04	2
19.63	2		
27.32	5		
Oct. 12.35	3		
26.18	4		

8598. *U Pegasi.*

1897 Oct. 23; seven observations, from $11^h 57^m$ to $15^h 14^m$, yield as the time of maximum $12^h 46^m$ Gr. M.T.

1897 Oct. 24; eight observations, from $11^h 52^m$ to $15^h 32^m$, yield as the time of minimum $13^h 47^m$ Gr. M.T. The minimum was well observed.

1897 Oct. 25; seven observations, from $11^h 44^m$ to $14^h 50^m$, indicate as the time of maximum $13^h 52^m$ Gr. M.T.

1897 Oct. 26; sixteen observations, from $11^h 50^m$ to $19^h 24^m$, yield two maxima and the intervening minimum, as follows:

Maximum	$12^h 56^m$ Gr. M.T.
Minimum	15 47
Maximum	17 59

The minimum is quite flat at the bottom, so that the time is considerably uncertain.

OBSERVATIONS OF COMET *b* 1898,

MADE AT THE OBSERVATORY OF VASSAR COLLEGE,

BY CAROLINE E. FURNESS.

1898 Greenwich M.T.	*	No. Comp.	☌ − * $\Delta\alpha$	☌ − * $\Delta\delta$	☌'s apparent α	☌'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
Mar. 25 $21^h 50^m 19^s$	1	11	$+0^m 9^s.71$	$-6' 58''.1$	$21^h 40^m 40^s.03$	$+22° 48' 37''.5$	*n*9.646	0.645
Apr. 3 21 46 5	2	5	+2 10.76	−0 12.5	22 18 56.59	+32 1 1.8	*n*9.688	0.572
7 21 10 43	3	11	+1 51.14	−1 10.4	22 35 15.25	+35 21 18.4	*n*9.724	0.603
8 21 11 10	4	10	−0 27.16	−8 50.7	22 40 23.70	+36 13 50.2	*n*9.729	0.598
12 21 7 53	5	10	−1 31.70	+0 41.9	22 59 26.63	+39 33 0.6	*n*9.751	0.580

Mean Places for 1898 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	$21^h 40^m 29^s.81$	$+0^s.51$	$+22° 55' 44''.1$	$-8''.5$	Becker, Berlin A.G. Catal. 8377
2	22 16 45.57	+0.26	+32 1 19.3	−5.0	Leiden A.G. Zones. 2 obs.
3	22 33 53.91	+0.20	+35 22 33.3	−4.5	" " " 2 obs.
4	22 40 50.68	+0.18	+36 22 45.1	−4.2	" " " 2 obs.
5	23 0 58.17	+0.16	+39 32 21.9	−3.2	" " " 3 obs.

FILAR-MICROMETER OBSERVATIONS OF COMET *b* 1898,

MADE WITH THE 12-INCH EQUATORIAL OF THE DETROIT OBSERVATORY, ANN ARBOR, MICH.,

BY SIDNEY D. TOWNLEY.

[Communicated by the Director of the Observatory.]

1898 Ann Arbor M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
Mar. 24 16 56 35	1	8, 6	+0 32.19	+4 51.9	21 36 54.09	+21 48 38.6	*n*9.637	0.658
29 15 46 20	2	8, 6	+1 57.39	−1 41.8	21 56 35.87	+26 50 46.7	*n*9.688	0.700
31 15 54 20	3	10, 6	+0 48.07	+2 56.3	22 4 56.55	+28 49 49.8	*n*9.695	0.681
Apr. 2 16 3 34	4	10, 8	+0 20.59	+1 45.7	22 13 30.78	+30 46 19.1	*n*9.701	0.658
6 15 59 38	5	10, 8	−1 21.01	+4 54.5	. . . .	. . . .	*n*9.720	0.641
11 14 53 49	6	10, 8	+1 30.10	−2 18.0	22 54 28.29	+38 43 26.2	*n*9.742	0.725
15 15 22 46	7	10, 8	−0 25.25	−0 55.8	23 14 15.36	+41 50 11.8	*n*9.768	0.669

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 36 21.22	+0.38	+21 43 52.6	−5.9	Becker, Berlin A.G. Catal. 8343
2	21 54 38.14	+0.34	+26 52 34.0	−5.5	Graham, Camb. (Engl.) A.G. Catal. 13071
3	22 4 8.17	+0.31	+28 46 58.7	−5.2	" " " " " 13221
4	22 13 9.91	+0.28	+30 44 38.5	−5.1	DM. +30°4670. Micr. deter. from *8
5	22 32 33.4	+0.21	+34 23.6	−4.5	DM. +34°4731*
6	22 52 58.01	+0.18	+38 45 47.9	−3.7	$\frac{1}{3}$ (2 Yarn. 10387 + W. Bessel 1176)
7	23 14 40.47	+0.14	+41 51 10.3	−2.7	DM. +41°4748. Micr. deter. from *9
8	22 16 23.37	. .	+30 47 51.6	. .	$\frac{1}{3}$ (2 Kam 4484 + W. Bessel 326)
9	23 14 48.08	. .	+41 41 46.2	. .	Bonn A.G. Catal. 17665

* No brighter star for nearly a degree in any direction.

EPHEMERIS OF COMET *b* 1898,

BY C. D. PERRINE.

(Computed from Elliptic Elements on p. 24, for Greenwich Midnight.)

1898	True α	True δ	log Δ	Br.	1898	True α	True δ	log Δ	Br.
	h m s	° ′				h m s	° ′		
June 2.5	3 17 27	+56 17.9	0.3638	0.21	June 16.5	4 10 11	+55 53.7		
4.5	25 42	17.8			18.5	16 47	46.9	0.4005	0.15
6.5	33 43	16.3	0.3738	0.19	20.5	23 11	39.6		
8.5	41 29	13.6			22.5	29 22	31.8	0.4083	0.14
10.5	49 1	9.8	0.3833	0.18	24.5	35 21	23.8		
12.5	3 56 18	5.3			26.5	4 41 7	+55 15.4	0.4154	0.13
14.5	4 3 21	+56 0.0	0.3922	0.16					

Unit of brightness is that at discovery.

CONTENTS.

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SECULAR PERTURBATIONS OF *VENUS* FROM THE ACTION OF *SATURN*.

By ERIC DOOLITTLE.

The elements employed in the following computation are from Dr. G. W. Hill's "*New Theory of Jupiter and Saturn*." pp. 19, 192, 554 and 558.

Venus.	*Saturn.*
$\pi = 129°\ 27'\ 42''.83$	$\pi' = 90°\ 6'\ 41''.37$
$i = 3\ 23\ 35.01$	$i' = 2\ 29\ 40.19$
$\Omega = 75\ 19\ 53.08$	$\Omega' = 112\ 20\ 49.05$
$e = 0.006\,84311$	$e' = 0.056\,06025$
$\log a = 9.859\,3378$	$\log a' = 0.979\,4956$
$m = \frac{1}{408134}$	$m' = \frac{1}{3501.6}$

Epoch 1850.0 G.M.T.

The orbit of *Venus* was divided into twelve parts with regard to the eccentric anomaly. An examination of the final sums renders it evident that a division into six parts would have been entirely sufficient, since, in this case, the greatest disagreement occurs in the computation of $\left[\frac{de}{dt}\right]_{00}$, of which the value computed from the six even points of division differs from that obtained from the remaining points, by $0''.000\,000\,015$. The employment of the larger number of divisions guards against very large errors in the first part of the computation (except in the case of ϵ and the functions immediately dependent upon it), and it also may be regarded as furnishing two different determinations of the differential coefficients, which are to a certain extent independent.

The work has been carried twice through from the beginning at different times, and the usual test equations have been applied. The logarithms of N, P, and Q, in this and the previous computations, were also tested by forming Σ_1 and Σ_2 for the denominator of $\sin\theta$, which is the modulus of the elliptic integrals used in the computation.

The constants of the orbit and the auxiliary functions are as follows:

$I = 2°\ 3'\ 12''.946$	$\log k = p9.999\,7836$
$II = 281\ 7\ 33.71$	$\log k' = p9.999\,9375$
$II' = 241\ 43\ 52.16$	$\log c = p9.456\,3013$
$K = 39\ 24\ 36.81$	$c = 0.285\,95737$
$K' = 39\ 22\ 46.29$	

E	log r	v	ϵ	A	log B	g	h
°		° ′ ″	° ′ ″				
0	9.856 3557	0 0 0.00	22 39 58.58	92.098 86822	1.051 6358	5.386 574	90.704 833
30	9.856 7564	30 11 47.87	40 35 15.14	91.774 34432	0.993 9889	11.773 870	90.705 340
60	9.857 8493	60 20 24.50	59 48 19.04	91.378 61335	0.893 6445	13.090 030	90.705 178
90	9.859 3378	90 23 31.50	82 36 49.62	91.017 72022	0.727 4070	8.014 522	90.704 527
120	9.860 8213	120 20 20.31	120 8 41.60	90.788 37022	0.442 5459	1.641 279	90.704 015
150	9.861 9040	150 11 43.65	213 32 1.64	90.752 01302	0.319 3695	0.379 833	90.704 174
180	9.862 2996	180 0 0.00	266 34 8.16	90.918 38168	0.644 2287	5.536 055	90.704 848
210	9.861 9040	209 48 16.35	292 10 14.16	91.242 89335	0.844 6971	11.994 380	90.705 369
240	9.860 8213	239 39 39.69	312 12 46.62	91.638 59982	0.964 5273	13.322 485	90.705 222
270	9.859 3378	269 36 28.50	330 26 49.72	91.999 48069	1.035 6208	8.196 630	90.704 548
300	9.857 8493	299 39 35.50	347 58 2.26	92.228 84301	1.071 1060	1.724 250	90.704 026
330	9.856 7564	329 48 12.13	5 15 37.87	92.265 22467	1.076 2066	0.341 433	90.704 165
Σ_1	9 155 9965	900 0 0.00	1129 21 56.26	549.051 67630	5.067 6882	40.700 673	544.228 122
Σ_2	9.155 9964	1080 0 0.00	964 36 48.15	549.051 67637	4.997 2899	40.700 668	544.228 123

E	l	G	G'	G''	θ	$\log \mathfrak{K}$	$\log \mathfrak{L}'$	$\log \mathfrak{N}$
°					° ″			
0	+1.108 078	90.704 1702	1.159 9384	0.051 1977	6 38 1.200	0.004 37971	0.278 83659	0.182 65168
30	+0.783 048	90.703 8960	0.924 8448	0.140 5539	6 12 59.177	0.003 84466	0.278 12417	0.181 85352
60	+0.387 477	90.703 5801	0.621 3419	0.232 2660	5 33 35.601	0.003 07377	0.277 09752	0.180 69890
90	+0.027 235	90.703 5526	0.311 6929	0.283 4826	4 38 20.618	0.002 13852	0.275 85161	0.179 29758
120	−0.204 603	90.703 8159	0.067 3331	0.268 7363	3 29 4.472	0.001 20578	0.274 60866	0.177 89917
150	−0.238 418	90.704 1279	0.016 4527	0.254 5245	3 7 43.816	0.000 97200	0.274 29705	0.177 54895
180	−0.072 423	90.704 1756	0.213 7666	0.285 5179	4 14 53.293	0.001 79285	0.275 39102	0.178 77951
210	+0.251 567	90.703 9071	0.511 5373	0.258 5083	5 16 44.963	0.002 77061	0.276 69370	0.180 24473
240	+0.647 420	90.703 5910	0.826 7173	0.177 6657	6 2 4.051	0.003 62228	0.277 82805	0.181 52050
270	+1.008 976	90.703 5405	1.092 6849	0.082 7021	6 32 0.533	0.004 24801	0.278 66126	0.182 45753
300	+1.238 859	90.703 8135	1.254 2286	0.015 1565	6 47 36.301	0.004 59387	0.279 12172	0.182 97533
330	+1.275 102	90.704 1229	1.278 0897	0.002 9452	6 49 30.415	0.004 63699	0.279 17912	0.183 03987
Σ_1	+3.107 808	544.223 1463	4.143 3262	1.030 5401	32 45 14.918	0.018 66826	1.662 88356	1.084 52839
Σ_2	+3.107 809	544.223 1470	4.135 3023	1.022 5166	32 37 19.522	0.018 61079	1.662 80691	1.084 44218

E	$\log N$	$\log P$	$\log Q$	$\log V$	J'_1	J_2	J_3	F_2
°								
0	6.639 6204	3.002 7123	4.864 4028	4.864 0969	90.642 62161	+0.265 81387	−3.152 9304	−22.089 684
30	6.639 2492	3.000 7786	4.862 8053	4.861 9670	90.778 21079	+0.417 97337	−2.412 6056	−32.658 241
60	6.640 0076	2.999 6349	4.861 9713	4.860 5842	90.924 03274	+0.414 81456	−1.016 7115	−34.435 270
90	6.641 6827	2.999 5754	4.862 0009	4.860 3076	90.982 37184	+0.274 23234	+0.660 7234	−26.944 615
120	6.643 8207	3.000 6087	4.862 8099	4.861 2040	90.921 21232	+0.076 49557	+2.170 2330	−12.193 388
150	6.645 8518	3.002 4609	4.864 5567	4.863 0356	90.853 55551	−0.100 22240	+3.107 3439	+ 5.865 829
180	6.647 2415	3.004 6480	4.867 0287	4.865 3231	90.876 94181	−0.225 07782	+3.220 9585	+22.394 088
210	6.647 6234	3.006 5929	4.869 0060	4.867 4620	90.895 57561	−0.305 95380	+2.480 6343	+32.962 649
240	6.646 8912	3.007 7706	4.869 9373	4.868 8763	90.868 58755	−0.346 89500	+1.084 7396	+34.739 680
270	6.645 2313	3.007 8524	4.869 6687	4.869 1748	90.782 19477	−0.321 68268	−0.592 6962	+27.249 019
300	6.643 0830	3.006 8083	4.868 3601	4.868 2695	90.669 00008	−0.195 22740	−2.102 2048	+12.497 792
330	6.641 0259	3.004 9227	4.866 4247	4.866 4070	90.602 46403	+0.025 57719	−3.039 3154	− 5.561 423
Σ_1	9.860 6644	8.022 1828	9.194 5101	9.188 3540	544.902 39611*	−0.010 07622	+0.204 0844	+ 0.913 218
Σ_2	9.860 6643	8.022 1829	9.194 4623	9.188 3540	544.894 37255*	−0.010 07598	+0.204 0844	+ 0.913 218

* When the term in G'' is removed, the sums are as follows: 543.871 85601 543.871 85600.

E	F_3	R_0	S_0	W_0	$\frac{1}{a} S^{(n)}$	$\frac{1}{a} \sin E\, R^{(n)}$
°						
0	−0.151 78108	0.000 218 24849	−0.000 000 278 9044	−0.000 023 072 725	−0.000 000 388 2394	+0.000 000 00000
30	−0.768 55930	0.000 218 11010	−0.000 000 229 9898	−0.000 017 634 117	−0.000 000 319 8543	+0.000 151 66640
60	−1.166 57105	0.000 218 52784	−0.000 000 431 5220	−0.000 007 491 896	−0.000 000 598 6233	+0.000 262 53554
90	−0.946 59087	0.000 219 09707	−0.000 000 703 7836	+0.000 004 695 343	−0.000 000 972 9742	+0.000 302 89965
120	−0.328 71848	0.000 219 63056	−0.000 000 665 3491	+0.000 015 732 681	−0.000 000 916 7023	+0.000 262 06084
150	+0.067 75179	0.000 220 23472	−0.000 000 141 2236	+0.000 022 675 427	−0.000 000 194 0900	+0.000 151 33936
180	−0.155 99309	0.000 221 03492	+0.000 000 612 8516	+0.000 023 605 169	+0.000 000 841 5031	−0.000 000 00000
210	−0.778 84429	0.000 221 86276	+0.000 001 091 8347	+0.000 018 202 966	+0.000 001 500 5585	−0.000 152 45807
240	−1.180 17310	0.000 222 25231	+0.000 000 971 7617	+0.000 007 900 358	+0.000 001 338 8702	−0.000 265 18905
270	−0.959 86467	0.000 221 80036	+0.000 000 394 4793	−0.000 004 483 114	+0.000 000 545 3639	−0.000 306 63694
300	−0.338 10816	0.000 220 57741	−0.000 000 171 9598	−0.000 015 556 236	−0.000 000 238 5490	−0.000 264 99777
330	+0.064 76239	0.000 219 16657	−0.000 000 374 4378	−0.000 022 338 577	−0.000 000 520 7429	−0.000 152 40100
Σ_1	−3.321 34496	0.001 320 27153†	+0.000 000 036 8780	+0.000 001 117 351	+0.000 000 038 2593	−0.000 005 59044
Σ_2	−3.321 34495	0.001 320 27158†	+0.000 000 036 8792	+0.000 001 117 928	+0.000 000 038 2610	−0.000 005 59070

† Upon adding the corresponding logarithms, there is obtained: 8.055 01910 8.055 01915.

E	$+R_0 \sin v$ $+S_0(\cos v+\cos E)$	$-R_0 \cos v$ $+S_0\left(\frac{r}{a}\sec^2\varphi+1\right)\sin v$	$W_0 \cos u$	$W \sin u$	$-2\frac{r}{a}R$
0°	−0.000 000 55781	−0.000 218 24849	−0.000 013 519 262	−0.000 018 697 064	−0.000 433 51010
30	+0.000 109 30468	−0.000 188 74417	−0.000 001 743 111	−0.000 017 547 753	−0.000 433 63510
60	+0.000 189 46670	−0.000 108 88722	+0.000 003 103 342	−0.000 006 818 927	−0.000 435 56030
90	+0.000 219 09678	+0.000 000 09174	−0.000 003 823 625	+0.000 002 725 094	−0.000 438 19414
120	+0.000 190 22138	+0.000 109 78821	−0.000 015 659 442	+0.000 001 516 257	−0.000 440 76418
150	+0.000 109 71092	+0.000 190 96268	−0.000 020 662 231	−0.000 009 340 619	−0.000 443 07990
180	−0.000 001 22570	+0.000 221 03492	−0.000 013 831 594	−0.000 019 129 016	−0.000 445 09495
210	−0.000 112 16824	+0.000 191 42744	−0.000 001 923 256	−0.000 018 101 079	−0.000 446 35520
240	−0.000 192 79204	+0.000 110 58265	+0.000 003 187 081	−0.000 007 228 982	−0.000 446 02556
270	−0.000 221 79790	+0.000 000 72885	−0.000 003 614 847	+0.000 002 651 640	−0.000 443 60072
300	−0.000 191 84805	−0.000 108 85437	−0.000 015 464 964	+0.000 001 682 669	−0.000 439 64535
330	−0.000 110 88191	−0.000 189 05102	−0.000 020 417 779	−0.000 009 062 352	−0.000 435 73540
Σ_1	−0.000 006 73552	+0.000 005 41570	−0.000 052 184 839	−0.000 048 675 063	−0.002 640 60044
Σ_2	−0.000 006 73567	+0.000 005 41552	−0.000 052 184 849	−0.000 048 675 069	−0.002 640 60046

The equation. $\sin q \cdot \frac{1}{2} A_1^{(s)} + \cos q \cdot B_0^{(c)} = 0$, is found to give the residual $+0''.000\,000\,000\,000\,29$.

If m' is left indefinite, the resulting values of the differential coefficients are the following:

		log coeff.
$\left[\frac{de}{dt}\right]_{00} = -\;2''.3648522\; m'$		$n0.373\,8040$
$\left[\frac{d\pi}{dt}\right]_{00} = +277.35124\; m'$		$p2.443\,0301$
$\left[\frac{d\chi}{dt}\right]_{00} = +277.85744\; m'$		$p2.443\,8220$
$\left[\frac{di}{dt}\right]_{00} = -\;18.322835\; m'$		$n1.262\,9927$
$\left[\frac{d\Omega}{dt}\right]_{00} = -288.76199\; m'$		$n2.460\,5400$
$\left[\frac{dL}{dt}\right]_{00} = -927.63054\; m'$		$n2.967\,3751$

If we adopt the mass given above for *Saturn*,

$$(m' = 1 \div 3501.6),$$

the following values finally result:

$$\left[\frac{de}{dt}\right]_{00} = -0''.000\,675\,36338 \qquad \left[\frac{di}{dt}\right]_{00} = -0''.005\,232\,7048$$

$$\left[\frac{d\pi}{dt}\right]_{00} = +0.079\,207\,000 \qquad \left[\frac{d\Omega}{dt}\right]_{00} = -0.082\,465\,731$$

$$\left[\frac{d\chi}{dt}\right]_{00} = +0.079\,351\,564 \qquad \left[\frac{dL}{dt}\right]_{00} = -0.264\,91624$$

The values obtained by LEVERRIER are found in the *Annales de l'Observatoire de Paris*, Tome II, chapter 7, and Tome VI, page 6. Those of NEWCOMB are stated on pages 336 and 376 of his "*Secular Variations of the Four Inner Planets.*" Upon reducing the results of LEVERRIER to the above value of m', the three series of values compare as follows:

	Results of LEVERRIER	Results of NEWCOMB	Method of GAUSS
$\left[\frac{de}{dt}\right]_{00} =$	−0″.00067	−0″.00067	−0″.00067536
$e\left[\frac{d\pi}{dt}\right]_{00} =$	+0.00055	+0.00054	+0.00054202
$\left[\frac{di}{dt}\right]_{00} =$	−0.00523	−0.00523	−0.00523270
$\sin i\left[\frac{d\Omega}{dt}\right]_{00} =$	−0.00489	−0.00488	−0.00488077
$\left[\frac{dL}{dt}\right]_{00} =$	−0.265	–	−0.26491624

The Flower Observatory, 1898 *June* 1.

NOTES ON VARIABLE STARS, — No. 24,

BY HENRY M. PARKHURST.

7792 *SS Cygni.* By means of the extended list of comparison-stars appended, several independent comparisons may be made on the same evening. The most accurate determination of the period may be derived from the time of ascent, using this term to indicate equality with the mean of W and $1\,W$, at which time it is rising at the rate of two magnitudes per day, adding 2.00 days for the highest point, although in the "long" maxima (*A.J.* 434), the apparent maximum may be one or two days later.

(857) — *Ceti.* For four successive years I have observed this variable photometrically (*A.J.* 346, 377, 400). That it has not yet been confirmed appears to be due either to the

absence of suitable comparison-stars in convenient proximity for use in estimations, or to an occasional irregularity, the law of which is not yet determined. At the periods 38, 41, 43, 57 and 59, the maximum appears to have occurred about two days earlier; but the observations were so interrupted by clouds that the times could not be determined. Arbitrarily rejecting the observation of 3269, sufficiently disposes of the abnormal correction at that maximum. It is now possible to verify the period by the early observations; from which, combined with the observations of the present year, I deduce the elements: 3213.00 + 17.41 E; for which the maxima heretofore published show the following corrections:

E	Comp.	Corr.	W.	E	Comp.	Corr.	W.
−149	0618.91	−2.9	2	+17	3508.96	+0.4	5
65	2081.35	−1.3	1	18	3526.37	−0.3	5
17	2394.73	−0.7	4	19	3543.78	+0.1	5
0	3213.00	−1.4	2	20	3561.19	+0.2	3
+ 2	3247.82	+0.4	8	21	3578.60	−0.6	3
3	3265.23	+3.4	3	22	3596.01	−0.2	1
14	3456.73	+0.3	4	23	3613.42	+0.1	2
15	3474.14	+0.4	1	24	3630.83	0.0	1
+ 16	3491.55	0.0	5	+37	3857.16	−0.6	5

Results of Observations.

No.	Star	Phase	Observed Date		E	Corr.	W	Mag.	Factors			Remarks
			Julian	Calendar 1897–98							d	
513	*R Piscium*	Max.	4295	Jan. 5	33	+17	9	9.10	0.93	1.27	23	
715	*S Arietis*	Max.	4218	Oct. 20	32	+ 1	9	10.59	0.24	0.44	11	Compared with two asteroids
782	*R Arietis*	Max.	4236	Nov. 7	61	+ 8	7P	8.55	0.52	0.80	29	
806	*o Ceti*	Max.	4248	Nov. 19	34	+10	9	3.20	0.69	0.74	43	
"	"	Max.	4255	Nov. 26	34	+17	9P	3.11	0.64	0.75	16	
845	*R Ceti*	Max.	4227	Oct. 29	67	+10	5P	7.8	–	–	–	
(857)	*— Ceti*	Max.	4205.36	Oct. 7	57	–	E	8.6	–	–	–	Interrupted
"	"	Max.	4240.18	Nov. 11	59	–	E	8.6	–	–	–	"
"	"	Max.	4275.9	Dec. 16	61	+0.9	8	8.71	0.16	0.19	7	See note above
"	"	Max.	4291.4	Jan. 1	62	−1.0	5	8.65	–	–	–	"
893	*U Ceti*	Max.	4231	Nov. 2	20	− 7	4	7.5	0.6	0.6	25	
"	"	Max.	4237	Nov. 8	20	− 1	6P	6.9	–	–	–	
906	*R Trianguli*	Max.	4311	Jan. 21	10	0	2	5.13	0.97	0.83	83	Proportionate factors
1113	*U Arietis*	Max.	4260	Dec. 1	5	+40	5	9.24	–	–	–	−16, by elements *A.J.* 403
1166	*X Ceti*	Min.	4218	Oct. 20	–	–	2	.12]	–	–	–	
"	"	Max.	4321	Jan. 31	–	–	9	9.40	0.45	0.35	18	Period probably 178 days
"	"	Max.	4320	Jan. 30	–	–	5P	9.40	0.45	0.35	18	Reducing with same constants
1357	*U Eridani*	Max.	4268 :	Dec. —	–	–	1	–	–	–	–	
1386	*T Eridani*	Max.	4333	Feb. 12	12	−13	8	8.46	0.65	0.48	19	
1577	*R Tauri*	Max.	4272	Dec. 13	40	+10	6	9.39	–	–	–	Correction unchanged
"	"	Max.	4248	Nov. 19	40	−14	8P	9.2	–	–	–	Highest point on Dec. 11
1582	*S Tauri*	Max.	4313	Jan. 23	37	−36	9P	9.7	1.0	1.0	67	Confirms corr. of last year
1717	*V Tauri*	Max.	4241	Nov. 12	54	+ 6	5	9.85	0.45	0.85	38	
"	"	Max.	4242	Nov. 13	54	+ 7	8P	10.11	0.50	0.69	31	
"	"	Min.	4323	Feb. 2	55	0	6	13.6	1.1	1.2	142	Interpolation of 95d by factors
1761	*R Orionis*	Min.	2925 :	April —	38	+33	1	12.0]	–	–	–	1894
"	"	Min.	3276 :	Mar. —	39	+ 4	1	12.2]	–	–	–	1895
"	"	Max.	3866	Nov. 2	40	0	2	10.5	–	–	–	1896
"	"	Max.	4230	Nov. 1	41	−16	2P	10.5	–	–	–	1897
1803	*T Leporis*	Max.	4223	Oct. 25	8	–	E	–	–	–	–	Diminishing in the winter
2013	*U Aurigae*	Max.	4192	Sept. 24	6	–	E	–	–	–	–	
2100	*U Orionis*	Max.	4377	Mar. 28	12	0	6P	6.1	0.7	0.7	23	[min. midway
2266	*V Monocerotis*	Min.	4334	Feb. 13	17	+ 3	2	–	–	–	–	Assuming equal factors and

Individual Observations.

Including Observations by Arthur C. Perry.

513 *R Piscium*. (Continued from 400.)

Julian	Calendar 1897	Mag.
4214.5	Oct. 16	11.2
4215.6	17	10.76_2
4228.5	30	11.24_2
4256.6	Nov. 27	10.39_2
4271.5	Dec. 12	9.31_2

513 *R Piscium*.—Cont.

Julian	Calendar 1897	Mag.
4272.5	Dec. 13	9.30_2
4278.6	19	9.53_2
4284.5	25	9.39_2
4285.5	26	9.13_2
4287.5	28	9.31_2

513 *R Piscium*.—Cont.

Julian	Calendar 1898	Mag.
4293.5	Jan. 3	8.82_2
4297.5	7	9.28_2
4303.5	13	9.11
4316.5	26	9.38_2
4325.5	Feb. 4	9.62_2
4327.5	6	9.51_2

715 *S Arietis*. (Continued from 400.)

Julian	Calendar 1897	Mag.
4168.6	Aug 31	12.0]P
4172.7	Sept. 4	13.0]
4197.6	29	10.93
4200.5	Oct. 2	10.97_2
4213.5	15	11.05_2

715 *S Arietis*.—Cont.

Julian	Calendar 1897	Mag.
4214.5	Oct. 16	10.84_2
4214.6	16	10.90_2
4215.5	17	10.70_2
4215.5	17	11.1P
4216.5	18	10.43_2
4224.6	26	10.67_2

715 *S Arietis.*—Cont.

Julian	Calendar	Mag.
	1897	
4228.5	Oct. 30	11.19_2
4231.6	Nov. 2	11.14

782 *R Arietis.*

(Continued from 400.)

Julian	Calendar	Mag.
	1897	
4224.6	Oct. 26	9.0P
4228.7	30	8.8P
4232.6	Nov. 3	8.5P
4246.6	17	8.6P
4252.7	23	8.8P
4258.7	29	9.4P
4270.5	Dec. 11	9.9P

806 *o Ceti.*

(Cont from 400. Comp. Stars 377)

Julian	Calendar	Mag.
	1897	
4193.6	Sept. 25	7.1
4200.7	Oct. 2	6.77_2
4213.6	15	6.11_2
4224.6	26	4.5P
4228.6	30	3.75_2
4228.7	30	4.4P
4232.6	Nov. 3	3.8P
4246.6	17	3.4P
4252.6	23	3.1P
4253.6	24	4.09_2
4253.6	24	3.1P
4256.5	27	3.43_2
4256.5	27	3.1P
4258.7	29	3.1P
4265.5	Dec. 6	3.46
4268.5	9	3.99_2
4270.5	11	4.17_2
4270.5	11	3.5P
4271.5	12	3.5P
4278.5	19	3.8P
4289.6	Dec. 30	4.1P
	1898	
4306.5	Jan. 16	4.9P

845 *R Ceti.*

(Continued from 400.)

Julian	Calendar	Mag.
	1897	
4224.6	Oct. 26	8.0P
4228.7	30	7.8P
4232.6	Nov. 3	8.0P
4246.6	17	9.0P
4252.6	23	8.9P
4258.7	29	9.9P
4270.5	Dec. 11	11.0P

(857) — *Ceti.*

(Cont. from 400. Comp. Stars 377)

Julian	Calendar	Mag.
	1897	
4200.6	Oct. 2	9.76_4
4201.6	3	9.98_5
4202.6	4	9.61_5
4203.6	5	9.16_5
4204.6	6	8.6;
4232.5	Nov. 3	9.88_2
4233.5	4	9.43_2
4238.6	9	8.6;
4239.5	10	9.02_2;

(857) — *Ceti.*—Cont.

Julian	Calendar	Mag.
	1897	
4270.5	Dec. 11	9.69_2
4271.6	12	9.83_2
4272.5	13	9.23_2
4274.6	15	9.06_2
4277.5	18	8.77_2
4278.5	19	9.34_2
4281.6	22	9.48_3;
4282.5	23	9.16
4283.5	24	9.43
4284.5	25	9.59
4285.5	26	9.80
4286.5	27	9.51
4287.5	28	9.42
4289.6	30	9.27_2
	1898	
4291.5	Jan. 1	8.66_2
4292.5	2	8.88

893 *U Ceti.*

(Cont. from 400. Comp. Stars 346)

Julian	Calendar	Mag.
	1897	
4214.6	Oct. 16	8.17_2
4224.7	26	7.4P
4228.6	30	7.74_2
4228.7	30	7.1P
4232.6	Nov. 3	7.48_2
4232.6	3	7.1P
4239.6	10	7.99_2
4246.6	17	7.6P
4252.6	23	7.4P
4258.7	29	7.6P
4278.5	Dec. 19	8.8P

906 *R Trianguli.*

(Continued from 377.)

Julian	Calendar	Mag.
	1897	
4271.5	Dec. 12	6.8P
	1898	
4345.5	Feb. 24	6.8
4354.5	Mar. 5	7.8

1113 *U Arietis.*

(Cont. from 403. Comp. Stars 314)

Julian	Calendar	Mag.
	1897	
4193.6	Sept. 25	11.6]
4200.6	Oct. 2	11.6]
4214.6	16	10.8]
4228.6	30	10.1
4256.5	Nov. 27	8.90_2
4270.5	Dec. 11	9.52_2
4271.6	12	9.12_2
4278.6	19	9.62_2
4285.5	26	9.47_2
	1898	
4295.5	Jan. 5	9.96_2

1166 *X Ceti.*

(Continued from 403.)

Julian	Calendar	Mag.
	1897	
4193.6	Sept. 25	11.3
4200.6	Oct. 2	11.97_2
4214.6	16	11.6]
4228.6	30	11.6]
4247.5	Nov. 18	11.0
4253.6	24	11.50_2
4258.7	29	11.3P

1166 *X Ceti.*—Cont.

Julian	Calendar	Mag.
	1897	
4270.5	Dec. 11	10.6P
4271.5	12	10.22_2
4272.5	13	10.76_2
4278.5	19	10.71_2
4278.6	19	10.7P
4285.5	26	11.36_2
4289.6	30	10.79_2
	1898	
4293.5	Jan. 3	10.78_2
4297.5	7	10.57_2
4306.5	16	10.3
4306.6	16	9.9P
4307.5	17	10.11_2
4314.5	24	9.87_2
4320.5	30	8.96_2
4325.5	Feb. 4	9.52_2
4327.5	6	9.58_2
4329.5	8	10.06_2
4331.5	10	10.10_2
4333.5	12	10.5P
4345.5	24	10.58_2
4345.5	24	10.3P
4354.5	Mch. 5	10.85_2
4358.5	9	10.2P

1357 *U Eridani.*

Julian	Calendar	Mag.
	1896	
3897.6	Dec. 3	11.2]
	1897	
3935.6	Jan. 10	12.0]
3956.5	31	11.5
3975.5	Feb. 19	10.4
4282.5	Dec. 23	10.4
4285.5	26	10.8
4286.5	27	11.33
	1898	
4330.5	Feb. 9	11.5]

1386 *T Eridani.*

(Continued from 377.)

Julian	Calendar	Mag.
	1896	
3897.6	Dec. 3	9.7
	1897	
3935.6	Jan. 10	10.3
3956.5	31	11.0]
3975.5	Feb. 19	11.0]
4282.5	Dec. 23	11.0
4286.5	27	11.34
	1898	
4331.5	Feb. 10	8.35
4333.5	12	8.87_2
4334.5	13	7.97_2
4335.5	14	8.79_2
4338.5	17	8.70_2
4347.5	26	8.43_2

1577 *R Tauri.*

(Continued from 403.)

Julian	Calendar	Mag.
	1897	
4228.7	Oct. 30	9.7P
4232.6	Nov. 3	9.5P
4246.6	17	9.2P
4252.6	23	9.2P

1577 *R Tauri.*—Cont.

Julian	Calendar	Mag.
	1897	
4253.6	Nov. 24	9.3P
4256.6	27	9.69_2
4258.7	29	9.5P
4270.5	Dec. 11	9.46_2
4270.5	11	9.1P
4271.5	12	9.7P
4272.5	13	9.32
4278.5	19	10.1P
4285.5	26	9.80_2
4290.6	30	10.8P
	1898	
4306.5	Jan. 16	10.8P

1582 *S Tauri.*

(Continued from 403.)

Julian	Calendar	Mag.
	1897	
4253.7	Nov. 24	11.2P
4258.7	29	11.7P
4270.5	Dec. 11	10.7]P
4278.6	19	11.8P
4290.6	30	10.5P
	1898	
4306.5	Jan. 16	10.1P
4333.6	Feb. 12	10.5P
4345.6	24	11.3P
4358.5	Mch. 9	11.5P
4363.5	14	11.8P
4374.6	25	11.2]P

1717 *V Tauri.*

(Continued from 403.)

Julian	Calendar	Mag.
	1897	
4224.7	Oct. 26	11.3]P
4228.6	30	10.4
4228.7	30	10.6P
4232.6	Nov. 3	10.27_2
4232.6	3	10.6P
4246.6	17	9.93_2
4246.6	17	10.0P
4252.7	23	10.0P
4256.6	27	9.94
4258.7	29	11.0P
4270.5	Dec. 11	11.4P
4270.6	11	11.00_2
4271.5	12	11.5P
4278.6	19	12.5P
4286.5	27	12.6
	1898	
4306.5	Jan. 16	13.0]
4338.5	Feb. 17	13.0
4345.6	24	12.3P]
4358.5	Mch. 9	13.0
4358.5	9	12.3]P
4363.5	14	12.3]P
4365.5	16	12.58_2
4371.5	25	12.25_2
4374.6	25	12.6P
4388.6	Apr. 8	11.0P

1761 *R Orionis.*

Julian	Calendar	Mag.
	1894	
2884	Feb. 24	11.6:
2895	Mch. 7	11.9
2911	23	12.0

1761 *R Orionis.*—Cont.

Julian	Calendar	Mag.
	1894	
2925	Apr. 6	12.0]
2941	22	10.0]
	1895	
3213.6	Jan. 19	11.1
3216.6	22	11.50_2
3236.5	Feb. 11	11.5
3242.6	17	11.9]
3248.5	23	11.93_2
3267.5	Mch. 14	12.1
3276.5	23	12.2]
3291.5	Apr. 10	12.1]
	1896	
3866.6	Nov. 2	10.5
3871.6	7	10.6
	1897	
4228.7	Oct. 30	10.5P
4232.6	Nov. 3	10.5P
4246.6	17	10.81_2
4246.7	17	10.6P
4252.7	23	10.6P
4258.7	29	10.6P
4271.5	Dec. 12	10.7P
4271.6	12	11.51_2
4278.6	19	10.7P
4286.5	27	11.08_2

1803 *T Leporis.*

(Continued from 377.)

Julian	Calendar	Mag.
	1897	
4285.6	Dec. 26	9.4:
4286.6	27	9.25_2
	1898	
4331.6	Feb. 10	11.0:

2013 *U Aurigae.*

(Continued from 350.)

Julian	Calendar	Mag.
	1897	
4200.7	Oct. 2	8.7
4202.6	4	8.7
4203.6	5	8.6:
4214.6	16	8.8
4221.7	23	8.9

2100 *U Orionis.*

(Continued from 403.)

Julian	Calendar	Mag.
	1898	
4345.6	Feb. 24	8.0P
4358.5	Mch. 9	6.8P
4363.6	14	6.3P
4374.6	25	6.2P
4388.6	Apr. 8	6.4P
4400.6	20	6.8P
4419	May 9	7.3]P

2267 *V Monocerotis.*

Cont. from 403. Comp. Stars 403

Julian	Calendar	Mag.
	1897	
4256.7	Nov. 27	9.8
4286.6	Dec. 27	11.1
	1898	
4331.5	Feb. 10	11.0]
4333.5	12	12.2]
4358.5	Mch. 9	12.0]
4365.5	16	13.0]
4374.6	25	12.8:
4393.5	Apr. 13	10.6

Comparison-Stars. — 1893–1897

7468 *T Aquarii.*				7502 *X Delphini.*				7792 *SS Cygni.*				7792 *SS Cygni.* — Cont.			
Star	DM.	Mag.	*n*	Star	DM.	Mag.	*n*	Star	DM.	Mag.	*n*	Star	DM.	Mag.	*n*
C	−6°5604	5.97	6*M*	1*I*	+16°4414	7.91	4	*K*	+43°4037	8.80	8	*Y*	+43°4027	10.43	3
D	−5°5410	6.79	3*M*	*L*	+17°4454	8.41	13	*L*	+42°4190	8.82	16	*Z*	+43°4022	10.55	1
F	−5°5382	7.20	9	*N*	+17°4451	8.78	12	*N*	+42°4195	8.22	10	1*Z*	+43°4019	10.42	2
I	−5°5396	7.97	22	*W*	+17°4449	9.99	14	*P*	+43°4030	9.14	8	2*Z*	+43°4015	10.55	2
L	−5°5393	9.15	27	*X*	+16°4418	9.68	2	*Q*	+43°4012	9.47	8	*b*	0.3*s* 2.0*p* 1*W*	10.65	4
N	−5°5401	8.70	15	*b*	1.9*n* 1.2*f X*	10.95	7	*S*	+43°4029	9.53	2	*c*	6.6*n* 1.7*p* *L*	10.67	6
1*N*	−5°5402	8.40	14	*e*	2.1*n* 2.4*f X*	11.54	4	*T*	+43°4028	9.76	2	*d*	0.4*s* 1.5*f* *W*	10.73	13
R	−5°5383	9.07	10	*h*	3.9*s* 3.8*p W*	12.11	2	*W*	+42°4186	9.78	19	*e*	0.3*n* 3.5*p W*	10.75	12
W	−5°5388	10.14	5*P*	*i*	3.8*s* 0.9*p W*	12.29	2	1*W*	+43°4020	9.78	15	*f*	5.2*n* 3.7*f W*	11.69	5
Z	−5°5389	11.46	5	*j*	*s f* *V*	12.73	1	2*W*	+43°4034	9.92	2	*g*	1.7*s* 1.0*f* *e*	11.70	6
l	5*n* *V*	13.17	2	*k*	*n f* *V*	12.74	1	*X*	+43°4033	10.06	2	*h*	0.3*n* 1.7*p* *d*	11.88	3
o	2*n*4*f* *V*	13.46	2	*l*	2*s*3*f* *W*	12.76	2	1*X*	+43°4032	10.47	2	*k*	0.9*s* *V*	12.06	2

OBSERVATIONS OF COMET 1896 V,

MADE WITH THE 36-INCH TELESCOPE OF THE LICK OBSERVATORY,

By WILLIAM J. HUSSEY.

1896–7	Mt. Hamilton M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Oct. 28	7 33 21	1	11 , 8	+0 13.00	−4 59.0	19 33 40.81	−13 42 32.6	9.470	0.811
29	7 34 44	3	8 , 8	+0 6.76	−3 30.9	19 36 55.50	−13 43 52.0	9.475	0.809
	8 8 46	3	8 , 8	+0 11.36	−3 31.7	19 37 0.10	−13 43 52.9	9.516	0.799
Nov. 1	7 23 47	4	8 , 8	+0 16.39	−0 46.1	19 46 41.41	−13 46 16.5	9.453	0.813
	7 43 6	4	8 , 8	+0 18.97	−0 45.1	19 46 43.99	−13 46 15.5	9.499	0.807
2	7 34 58	6	8 , 8	+0 13.68	+3 36.3	19 50 0.16	−13 46 31.0	9.482	0.809
Dec. 2	7 15 1	7	8 , 8	+0 10.81	+2 39.9	21 29 53.22	−11 48 48.2	9.475	0.800
6	7 5 34	9	4	. . .	+0 47.3	. . . .	−11 16 34.3	. .	0.799
	7 12 23	9	4	−0 1.06	. . .	21 42 58.21	. . . .	9.474	. .
	7 48 58	9	5 , 10	+0 4.18	+1 2.5	21 43 3.45	−11 16 19.1	9.548	0.787
7	7 18 0	11	5 , 5	−0 2.54	−0 7.3	21 46 13.74	−11 7 50.7	9.475	0.797
	8 3 28	11	11 , 5	+0 3.39	+0 9.1	21 46 19.67	−11 7 34.3	9.572	0.781
Jan. 4	7 18 45	13	8 , 8	+0 11.20	+1 5.6	23 12 37.99	− 6 6 38.7	9.532	0.763
	7 47 56	14	8 , 8	+0 4.78	−1 40.5	23 12 41.41	− 6 6 26.4	9.579	0.757
	8 6 31	14	3	. . .	−1 27.2	. . . .	− 6 6 13.1	. .	0.753

Mean Places for 1896–7.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	19 33 24.68	+3.13	−13 37 37.1	+ 3.5	Connected with *2
2	19 36 36.22	+3.13	−13 33 57.4	+ 3.7	Harvard Coll. Obs'y merid. circle. 3 obs.
3	19 36 45.61	+3.13	−13 40 24.8	+ 3.6	DM. −13°5448. Connected with *2
4	19 46 21.88	+3.14	−13 45 34.7	+ 4.3	Connected with *5
5	19 49 6.58	+3.15	−13 49 20.1	+ 4.5	Harvard Coll. Obs'y merid. circle. 3 obs.
6	19 49 43.34	+3.14	−13 50 11.8	+ 4.5	" " " " " 3 obs.
7	21 29 39.17	+3.24	−11 51 40.7	+12.6	Connected with *8
8	21 31 43.25	+3.25	−11 55 36.1	+12.7	Stone, Radcliffe Catal. 5830
9	21 42 56.00	+3.27	−11 17 7.9	+13.7	Connected with *10
10	21 40 51.92	+3.26	−11 17 52.3	+13.6	½ (Yarnall 9777 + Munich$_2$ 11972)
11	21 46 13.00	+3.28	−11 7 57.4	+14.0	Connected with *12
12	21 45 21.66	+3.28	−11 7 44.8	+13.9	Munich$_1$ 29648
13	23 12 26.53	+0.26	− 6 7 44.1	− 0.2	Vienna–v. Kuffner's Obs., Zones 185, 192
14	23 12 36.37	+0.26	− 6 4 45.7	− 0.2	" " Zone 179

All the measures are direct micrometer comparisons. Professor PICKERING has kindly furnished me the positions of some of the comparison-stars from Professor SEARLE's observations for the southern Cambridge (Mass.) A.G. Zone.

Mt. Hamilton, Cal., 1898 *May* 19.

OBSERVATIONS OF SUNSPOTS,

MADE AT THE BOSTON UNIVERSITY OBSERVATORY,

By L. O. TILLSON and F. J. H. MANSFIELD, Students in Astronomy.

W.M.T.	Groups		Spots in Groups		Isolated Spots		Totals		Def.
1897 d h	N.	S.	N.	S.	N.	S.	Gps.	Spots	
Oct. 8 4	0	0	0	0	1	1	0	2	F
12 22	2	0	6	0	0	0	2	6	E
13 23	1	0	4	0	0	0	1	4	F
14 23	1	0	5	0	1	0	1	6	F
17 23	1	0	2	0	0	0	1	2	F
18 23	1	0	3	0	0	0	1	3	F
19 22	0	1	0	2	0	1	1	3	P
22 23	0	0	0	0	0	0	0	0	F
26 0	0	0	0	0	0	0	0	0	F
26 23	0	0	0	0	0	0	0	0	P
29 2	0	0	0	0	0	0	0	0	P
30 2	0	0	0	0	0	0	0	0	P
Nov. 3 0	0	2	0	4	0	0	2	4	G
3 23	0	1	0	2	0	0	1	2	F
4 23	0	1	0	5	0	0	1	5	G
10 1	0	0	0	0	0	0	0	0	P
16 0	0	0	0	0	0	0	0	0	P
16 23	1	0	3	0	0	0	1	3	P
17 23	0	0	0	0	1	0	0	1	P
22 22	0	0	0	0	0	0	0	0	F
23 23	0	0	0	0	0	0	0	0	P
29 23	1	1	15	3	0	0	2	18	P
Dec. 1 23	1	0	17	0	0	1	1	18	P
5 22	1	2	6	12	2	0	3	20	G
10 0	2	1	39	6	0	0	3	45	G
10 22	2	1	40	6	0	0	3	46	G
12 22	2	0	46	0	0	0	2	46	G
15 3	2	0	27	0	2	0	2	29	F
16 2	2	0	22	0	2	0	2	24	G
18 0	3	0	22	0	1	0	3	23	F
21 3	0	0	0	0	1	0	0	1	P
21 23	0	0	0	0	1	0	0	1	P
22 23	0	0	0	0	1	0	0	1	F
23 23	0	0	0	0	0	0	0	0	P
26 22	1	1	2	3	0	0	2	5	E
28 22	1	0	2	0	1	0	1	3	F
31 22	1	0	2	0	1	0	1	3	F

W.M.T.	Groups		Spots in Groups		Isolated Spots		Totals		Def.
1898 d h	N.	S.	N.	S.	N.	S.	Gps.	Spots	
Jan. 2 22	1	0	2	0	2	0	1	4	E
5 0	3	0	7	0	0	0	3	7	G
6 23	2	0	7	0	1	0	2	8	E
9 22	0	0	0	0	2	0	0	2	P
10 23	1	0	2	0	0	0	1	2	F
12 23	0	0	0	0	1	1	0	2	F
17 0	0	2	0	19	1	0	2	20	P
20 0	0	3	0	9	2	1	3	12	P
21 3	1	3	3	13	1	0	4	17	G
23 22	2	0	21	0	0	1	2	22	F
24 23	2	0	18	0	0	1	2	19	P
27 23	1	0	3	0	0	0	1	3	P
Feb. 2 0	0	0	0	0	0	0	0	0	P
3 1	0	0	0	0	0	0	0	0	P
3 23	0	1	0	3	0	1	1	4	E
6 22	1	2	6	9	0	1	3	16	F
9 23	0	2	0	37	0	1	2	38	E
16 23	1	1	5	15	0	1	2	21	P
24 0	1	0	8	0	0	1	1	9	E
25 2	1	1	5	2	0	0	2	7	G
28 0	0	2	0	13	0	0	2	13	E
Mar. 1 23	0	2	0	8	0	0	2	8	F
3 2	0	3	0	9	0	0	3	9	F
7 0	1	3	6	28	0	0	4	34	P
8 3	1	2	8	70	0	1	3	79	F
8 23	1	2	7	60	0	1	3	68	E
10 1	1	2	8	60	0	1	3	69	G
14 3	1	1	4	40	0	0	2	44	E
14 23	1	1	4	21	0	0	2	25	F
17 1	0	2	0	6	2	0	2	8	E
24 22	0	1	0	2	0	0	1	2	F
31 22	0	1	0	2	0	0	1	2	P
Apr. 3 22	0	1	0	11	0	0	1	11	E
6 0	0	1	0	12	0	0	1	12	G
11 1	0	1	0	4	0	1	1	5	G
	49	51	387	496	27	16	100	926	

NOTES.

The letters P, F, G, E, under head of definition, stand, respectively, for poor, fair, good and excellent.

The total number of different groups observed was 35. Of these, 15 were north of the equator, and contained 126 spots, while 20 were south, and contained 168 spots. Of isolated spots, only 10 were noted, 5 being north and 5 south of the equator.

Concerning the spots presenting essentially symmetrical penumbras when well upon the disc, the following facts were noted while they were close to the limb. Five cases were recorded in which the penumbra showed upon the side away from the limb, and not on the side next the limb, while in eight cases the penumbra showed on the side next the limb, and not upon the opposite side. In five other cases the penumbra on the side next the limb was decidedly wider than upon the opposite side, although were not entirely wanting. In one case no penumbra was seen on either the east or the west side, though present on the north and south. One spot, which presented a symmetrical penumbra during its entire course across the disc, lost it upon all sides when close to the western limb. The only case of an umbra appearing to project was that of a spot immediately upon the eastern limb, on Dec. 29.

Pronounced maxima appear about Dec. 11 and Jan. 24, in both cases nearly all the spots being north of the equator. Other maxima appeared about Jan. 15, Feb. 10 and March 8, consisting chiefly of spots south of the equator.

From the measured latitudes and longitudes, it seems safe to conclude two, if not three cases of reappearance. First, the extensive northern disturbance, which was nearly central on the disc Dec. 12, reappeared in January greatly reduced in energy. Secondly, a group nearly central on Jan. 24, the largest member of which was in latitude $+4°$, and very near the prime meridian, reappeared in February much reduced in extent. Thirdly, a group which was first seen close to the eastern limb on Feb. 6, with a mean latitude $-5°$, longitude 100°, developed mainly upon its western side. Although the proof of reappearance is not conclusive, yet the extensive southern disturbance nearly central on March 11, was immediately adjacent to it, a portion of the areas even overlapping, while a very slight remnant was apparently present in April.

Of the 304 different spots observed, one-half were within ten degrees of the equator, and a large part of the remainder belonged to disturbed areas extending to within less than ten degrees of the equator. One spot was observed Feb. 24 exactly on the equator. No spot was found having a latitude as great as 20°.

OBSERVATIONS OF ASTEROIDS,

MADE AT THE CINCINNATI OBSERVATORY,

By EVERETT I. YOWELL.

1898 Cincinnati M.T.	✱	No. Comp.	Planet — ✱ $\Delta\alpha$	Planet — ✱ $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log Δp for α	log Δp for δ
			(247) *Eukrate.*					
	h m s		m s	″	h m s	° ′ ″		
Jan. 21 7 16 30	1	7	−0 27.93	+2 42.2	7 22 10.35	+60 45 7.6	n9.896	n9.737
27 10 20 40	2	8	+1 32.06	+3 53.5	7 17 37.70	+60 11 16.5	n9.038	n0.500
			(354) *Eleonora.*					
Mar. 15 8 29 29	3	8	+1 9.38	+2 33.3	10 55 33.26	+20 20 27.9	n9.521	0.539
24 9 35 50	4	7	−1 13.21	−2 14.3	10 50 9.61	+21 38 41.3	n9.453	0.490
			(82) *Alkmene.*					
Apr. 11 10 34 20	5	6	+4 25.68	+1 33.0	13 30 0.68	− 9 8 45.2	n9.267	0.812
15 10 0 34	6	6	−0 6.79	−0 33.2	13 26 27.22	− 8 53 40.7	n9.493	0.798
16 8 27 21	7	8	−0 56.21	+2 58.0	13 25 37.80	− 8 50 9.5	n9.546	0.791
20 11 25 16	8	8	−0 7.75	+5 3.1	13 22 4.24	− 8 35 2.7	7.027	0.814
			(24) *Themis.*					
May 19 10 12 52	9	6	+1 3.33	+1 31.3	14 20 40.26	−14 13 34.3	n8.531	0.849
21 10 20 58	10	8	−0 11.36	+7 22.9	14 19 25.58	−14 7 42.7	7.199	0.849
25 10 11 5	11	7	+3 23.08	−0 30.0	14 17 8.95	−13 57 6.3	8.263	0.848

Mean Places for 1898 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	7 22 33.34	+4.94	+60 42 23.1	+ 2.3	Helsingfors-Gotha A.G. Catal. 5104
2	7 16 0.81	+4.83	+60 7 19.3	+ 3.7	Comp. with Hels.-Gotha A.G. Catal. 5031
3	10 54 20.79	+3.09	+20 18 9.7	−15.1	Becker, Berlin G. Catal. 4151
4	10 51 49.73	+3.09	+21 41 9.6	−14.0	Becker. Berlin G. Catal. 4142
5	13 25 31.93	+3.07	− 9 9 58.4	−19.8	Munich I, 9237
6	13 26 30.90	+3.11	− 8 52 47.5	−20.0	½ (Schjellerup 4834 + Munich II, 4908)
7	13 26 30.90	+3.11	− 8 52 47.5	−20.0	½ (Schjellerup 4834 + Munich II. 4908)
8	13 22 8.89	+3.10	− 8 39 45.7	−20.1	½ (Munich I, 9186 + Munich II, 4880)
9	14 19 33.52	+3.41	−14 14 46.5	−19.1	Weisse's Bessel 14h307
10	14 19 33.52	+3.42	−14 14 46.5	−19.1	Weisse's Bessel 14h307
11	14 13 42.46	+3.41	−13 56 16.9	−19.4	Weisse's Bessel 14h192

COMET *c* 1898.

Prof. KEELER telegraphs the discovery, photographically, of a bright comet, by Mr. E. F. CODDINGTON, of the Lick Observatory. The following positions were obtained:

1898 June 11.7220 Gr.M.T.:	α = 16h 24m 45s.9 ;	δ = −25° 14′ 20″	Hussey
12.7288 "	16 21 34.1 ;	−25 52 43	Coddington

COMET *d* 1898 = ENCKE'S PERIODIC COMET.

Prof. KREUTZ telegraphs that ENCKE's comet was discovered at Mr. JOHN TEBBUTT's Observatory, Windsor, N.S.W., in the position: 1898 June 11.8435 Gr. M.T., $\alpha = 6^h\ 53^m\ 29^s.0$; $\delta = +11°\ 34'\ 0''$. From this it appears that the correction to the ephemeris in *A.J.* 436, p. 32, is, O−C, $\Delta\alpha = +9^s.5$; $\Delta\delta = +5'.2$.

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OBSERVATIONS OF DOUBLE-STARS,

MADE WITH THE 26-INCH REFRACTOR OF THE LEANDER McCORMICK OBSERVATORY,

By HERBERT R. MORGAN.

An eyepiece magnifying 1300 diameters has been used for most of the following observations. Columns 3 and 5 give the number of independent measures for each position-angle and distance published.

Σ 3062.

$\alpha = 0^h\ 1^m.0$; $\delta = +57°\ 53'$

	°		″	
1896.699	333.0	5	1.91	6
.715	331.8	4	2.05	6
.905	335.2	4	1.50	3
1896.773	333.3		1.82	

Σ 60.

$\alpha = 0^h\ 42^m.9$; $\delta = +57°\ 18'$

1896.675	209.9	6	4.75	3
.689	206.4	3	5.25	3
.691	208.6	3	4.93	6
.694	209.9	3	5.10	6
1896.687	208.7		5.01	

Σ 73.

$\alpha = 0^h\ 49^m.6$; $\delta = +23°\ 5'$

1896.905	16.4	4	1.24	3
.984	22.3	3	1.01	3
1896.944	19.4		1.12	

OΣ 38.

$\alpha = 1^h\ 57^m.8$; $\delta = +41°\ 51'$

1896.691	62.9	3	10.20	6
.694	62.9	4	10.10	6
.696	62.9	4	10.35	6
1896.694	62.9		10.22	

Σ 333.

$\alpha = 2^h\ 53^m.3$; $\delta = +20°\ 56'$

1896.905	204.7	3	1.28	4
.989	198.5	3	1.41	4
1896.947	201.6		1.34	

OΣ 53.

$\alpha = 3^h\ 11^m.0$; $\delta = +38°\ 16'$

	°		″	
1896.905	242.9	4	0.56	3
.929	242.1	3	0.56	3
.987	242.8	2	0.64	3
.989	241.9	2	0.46	2
1896.952	242.4		0.56	

Σ 460.

$\alpha = 3^h\ 53^m.7$; $\delta = +80°\ 25'$

1896.989	45.9	3	0.82	3

Σ 1037.

$\alpha = 7^h\ 6^m.6$; $\delta = +27°\ 23'$

1897.248	306.9	3	0.93	3
.250	302.6	4	1.03	4
1897.249	304.8		0.98	

Σ 1110.

$\alpha = 7^h\ 28^m.2$; $\delta = +32°\ 6'$

1897.234	228.3	4	5.50	3
.248	227.5	3	5.55	3
.261	225.5	3	5.63	3
1897.248	227.1		5.56	

Σ 1291.

$\alpha = 8^h\ 48^m.0$; $\delta = +30°\ 58'$

1897.234	324.1	4	1.44	3
.248	324.3	3	1.36	3
1897.241	324.2		1.40	

Σ 3121.

$\alpha = 9^h\ 11^m.9$; $\delta = +29°\ 0'$

1897.248	12.3	3	0.59	3
.250	13.2	3	0.54	3
.288	11.7	3	0.59	4
1897.262	12.4		0.57	

Σ 1338.

$\alpha = 9^h\ 14^m.2$; $\delta = +38°\ 39$

	°		″	
1897.261	163.0	3	1.48	3
.288	161.7	3	1.56	4
1897.274	162.4		1.52	

Σ 2130.

$\alpha = 17^h\ 3^m.2$; $\delta = +54°\ 36$

1896.776	330.8	5	2.23	3
.861	331.2	3	2.21	6
.872	331.5	3	2.13	3
1896.836	331.2		2.19	

Σ 2173.

$\alpha = 17^h\ 25^m.3$; $\delta = -0°\ 59'$

1896.696	154.8	3	1.19	6
.699	155.9	6	1.16	6
.715	152.7	3	1.17	6
1896.703	154.5		1.17	

Σ 2262.

$\alpha = 17^h\ 57^m.3$; $\delta = -8°\ 11$

1896.688	259.5	3	. .	
.685	260.9	3	1.98	3
.691	256.4	3	1.98	6
.696	256.0	3	1.96	5
1896.690	258.2		1.97	

Σ 2272.

$\alpha = 18^h\ 0^m.4$; $\delta = +2°\ 32$

1896.664	286.0	3	2.30	6
.674	287.1	3	2.25	4
.688	289.1	3	2.24	5
1896.675	287.4		2.26	

Σ 2382. $\alpha = 18^h\ 41^m.0$; $\delta = +39°\ 34'$

1896.735	10.7	4	3.02	3
.770	8.9	5	2.97	3
.773	12.1	4	2.95	3
1896.759	10.7		2.98	

Σ 2383. $\alpha = 18^h\ 41^m.0$; $\delta = +39°\ 31'$

1896.735	131.8	3	2.25	3
.770	130.5	3	2.18	3
.773	128.4	3	2.13	3
1896.759	130.2		2.19	

β 441. $\alpha = 20^h\ 13^m.0$; $\delta = +28°\ 50'$

1896.770	66.4	3	5.49	4
.776	65.6	3	5.61	3
.861	66.8	3	5.96	1
1896.802	66.3		5.70	

β 151. $\alpha = 20^h\ 32^m.9$; $\delta = +14°\ 15'$

1896.691	359.1	3	0.56	3
.697	356.0	4	0.46	6
.699	354.6	4	0.50	6
1896.696	356.6		0.51	

β 366 AB. $\alpha = 20^h\ 45^m.0$; $\delta = +50°\ 7'$

1896.880	152.3	6	1.86	4

Σ 2758. $\alpha = 21^h\ 2^m.3$; $\delta = +38°\ 14'$

1896.773	123.9	3	20.68(?)	4
.776	121.6	3	21.88	3
.861	123.6	3	21.78	3
1896.803	124.0		21.45	

β 75. $\alpha = 21^h\ 50^m.6$; $\delta = +10°\ 25'$

1897.792	39.3	3	1.27	3

OBSERVATIONS OF WINNECKE'S PERIODIC COMET = α 1898.

MADE AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,

By C. D. PERRINE.

1898 Mt. Hamilton M.T.		*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Jan. 20	16 58 37	1	d10 , 8	+0 2.34	−1 15.8	16 33 17.76	− 8 26 16.1	n9.577	0.772
	17 20 43	1	d10 , 8	+0 6.23	−1 30.5	16 33 21.65	− 8 26 30.8	n9.543	0.777
25	17 47 10	2	d 8 , 6	−0 26.43	+2 12.6	16 55 24.65	− 9 33 42.2	n9.497	0.789
28	17 34 36	3	12 , 6	−0 56.69	−0 54.5	17 9 0.98	−10 11 57.6	n9.526	0.787
29	17 14 53	4	d10 , 8	+0 3.98	+2 10.8	17 13 34.61	−10 25 14.5	n9.579	0.780
Feb. 18	16 55 1	6	d10 , 8	+0 39.67	+3 12.8	18 52 55.16	−13 39 0.6	n9.621	0.779
	17 17 18	8	d10 , 8	+0 0.28	+2 39.9	18 53 0.40	−13 39 5.8	n9.594	0.789
19	17 10 23	9	4	. . . .	+8 20.6	. . . .	−13 47 34.9	. .	0.785
	17 14 59	9	d 3	−0 21.72	. . .	18 58 11.09	. . . .	n9.600	. .
21	16 56 33	10	d10 , 8	−0 32.59	+0 25.8	19 8 37.25	−13 59 4.0	n9.624	0.780
28	17 22 11	12	3	. . . .	−3 15.7	. . . .	−14 25 50.6	. .	0.789
	17 28 23	12	6	−0 16.71	. . .	19 45 42.96	. . . .	n9.600	. .

Mean Places for 1898 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 33 15.02	+0.40	− 8 24 51.9	−8.4	$\frac{1}{3}$ (2 Rad.$_3$ 4322 + Schj. 5883)
2	16 55 50.63	+0.45	− 9 35 46.4	−8.4	$\frac{1}{4}$ (M$_1$ 13365 + 2 M$_2$ 6373 + W.B. 1005)
3	17 9 57.19	+0.48	−10 10 54.9	−8.2	$\frac{1}{3}$ (2 Paris 21822 + M$_1$ 13703)
4	17 13 30.14	+0.49	−10 27 17.2	−8.1	Micrometer-comparison with *5
5	17 11 23.55	+0.50	−10 33 56.5	−8.1	Lalande 31379
6	18 52 14.79	+0.70	−13 42 7.7	−5.7	S.DM. −13°5165. Micr.-comp. with *7
7	18 54 58.06	+0.69	−13 36 35.9	−5.6	Weisse's Bessel 1327
8	18 52 59.42	+0.70	−13 41 40.1	−5.6	S.DM. −13°5167. Micr.-comp. with *7
9	18 58 32.10	+0.71	−13 55 50.0	−5.5	Weisse's Bessel 1425
10	19 9 9.13	+0.71	−13 59 24.6	−5.2	Micrometer-comparison with *11
11	19 9 45.95	+0.71	−14 5 50.2	−5.1	Weisse's Bessel 158
12	19 45 58.93	+0.74	−14 22 31.3	−3.6	S.DM. −14°5575. Micr.-comp. with *13
13	19 44 48.53	+0.74	−14 22 4.2	−3.7	B.B. VI.

NOTES.

The observations of January 20, 28 and 29 were made with the 36-inch refractor, the others with the 12-inch refractor.— d indicates that $\Delta\alpha$ was measured directly with the micrometer. — January 20, observations made with 36-inch refractor. Comet very distinct; 30″ diameter. It shows a distinct central condensation, and at times a nucleus is suspected. Comet is fully as bright as a 14^M star. It is near a 6^M.8 star, and is easily seen. Seeing 1–2. High wind shakes telescope badly. — January 25, observations with 12-inch refractor. Comet faint and difficult to measure with this aperture. Seeing 2.— January 28, observations with 36-inch refractor. Comet is 30″–40″ diameter, and has a nucleus which sometimes appears stellar — about 16^M. Comet easy to measure. Seeing 2. — January 29, the residual in declination from an ephemeris indicated an error in the place of Lalande 31379. A rough micrometer comparison of this star with Rad.$_3$ 4514 on June 2 gave $\Delta\delta$ for the two stars = 2′ 36″.9. The Catalogue N.P.D. of Lalande 31379 is 100° 26′ 39″.8; in all probability it should be 100° 25′ 39″.8. Comet is as bright as a 13^M or 14^M star, and has a decided central condensation. No stellar point can be seen. Observations with 36-inch refractor. — February 18, observations with 12-inch refractor. Comet not difficult to measure; about 1′ diameter, with a central condensation of 12½^M to 13^M. Comet somewhat faint towards the end of measures—possibly some moisture

on object glass. Seeing 3. The declination of W. 1327 appears to be in error by 2′. The catalogue $\Delta\delta$ between W_1 1323 and 1327 is 3′ 5″.4, the observed $\Delta\delta$ on June 2 was 5′ 9″.4. The catalogue δ is —13° 42′ 10″.5: in all probability it should be —13° 44′ 10″.5. — February 19, observation stopped by clouds. — February 21, comet easy in 12-inch telescope — fully as bright as a 12^{M} star. Diameter 1′, central condensation. High north wind. Seeing 2. — February 28, measures of comet made in the dawn—transits somewhat uncertain. Seeing 3.

Mt. Hamilton, Cal., 1898 *June* 6.

SUNSPOT OBSERVATIONS.

MADE AT BERWYN, PENNA., WITH A 4½-INCH REFRACTOR.

BY A. W. QUIMBY.

1898		Time	New Grs.	Total Grs.	Total Spots	Fac. Grs.	Def.
Jan.	1	9	–	3	4	1	poor
	2	9	–	2	5	3	fair
	3	9	1	3	4	2	fair
	4	9	–	3	6	1	fair
	5	11	–	3	7	2	fair
	6	8	–	3	3	3	fair
	7	12	–	2	4	2	fair
	8	2	–	2	2	1	fair
	9	8	–	2	6	1	fair
	10	2	–	1	1		fair
	13	4	–	1	1	–	poor
	14	9	2	3	6	2	fair
	16	1	–	3	13	1	fair
	17	9	–	3	18	1	fair
	18	10	1	4	20	1	fair
	19	9	1	5	10	–	poor
	20	4	–	4	9	–	poor
	21	9	–	5	19	1	fair
	22	9	–	4	5	–	poor
	23	9	–	4	16	1	poor
	24	9	–	3	20	1	fair
	25	10	–	2	13	1	poor
	26	10	–	1	10	–	poor
	27	10	–	1	8	2	poor
	28	1	–	1	2	2	poor
	29	9	–	1	2	2	fair
	30	9	–	1	1	2	fair
Feb.	1	9	–	–	–	–	poor
	2	9	–	–	–	–	poor
	3	9	–	–	–	–	poor
	4	9	2	2	3	1	fair
	5	9	–	2	7	1	fair
	6	9	–	3	16	2	fair
	7	9	–	3	15	1	fair
	8	9	–	2	2		v.poor
	9	9	2	6	33	2	good
	10	10	–	3	29	2	good
	11	9	–	2	27	3	good
	12	2	–	2	39	1	good
	13	9	–	1	40	2	fair
	14	10	1	2	34	3	fair
	15	10	2	4	22	2	poor
	16	3	2	6	36	3	fair
	17	9	–	5	30	3	fair
	22	10	1	2	5	1	good
	23	10	–	2	10	3	good
	24	10	–	2	5	–	poor
	25	10	–	2	3	3	fair
	26	10	–	2	13	1	fair
	27	9	–	1	13	2	good
	28	8	1	2	12	3	good
Mar.	1	8	–	2	8	1	fair
	2	9	–	2	5	–	poor

1898		Time	New Grs.	Total Grs.	Total Spots	Fac. Grs.	Def.
Mar.	3	3	2	4	13	1	good
	5	9	2	4	13	2	good
	6	9	1	5	29	3	good
	7	1	–	5	24	1	poor
	8	9	–	5	74	1	good
	9	8	–	4	78		good
	10	11	–	4	80	2	fair
	11	11	–	4	62	1	fair
	12	9	–	4	45	–	poor
	13	8	–	3	58	2	fair
	14	8	–	3	22	3	poor
	15	8	–	2	12	2	poor
	*16	1	–	2	8	1	poor
	*17	1	1	2	6	1	poor
	*18	7	–	2	2	1	fair
	*19	4	–	–	–	–	poor
	*20	4	–	–	–	–	poor
	25	8	–	–	–	1	fair
	26	8	1	1	5	3	good
	28	3	–	1	2	–	poor
	29	11	–	–	–		poor
	30	12	–	–	–	2	fair
	31	8	2	2	2	1	fair
Apr.	1	8	1	2	3	1	fair
	2	8	–	2	3	1	fair
	3	8	–	2	5	1	fair
	4	8	–	2	7	1	fair
	6	8	–	1	12	1	good
	7	8	–	1	22	1	good
	8	8	–	1	7	1	fair
	9	8	1	2	7	1	poor
	10	8	–	2	14	2	good
	11	8	–	2	5	2	fair
	12	8	–	2	6	1	good
	13	8	–	2	2	1	poor
	14	8	–	–	–	1	fair
	16	8	–	–	–	–	fair
	17	8	–		–	–	poor
	18	8	–	–	–	–	fair
	19	10	–	–	–	–	v.poor
	20	8	–	–	–	–	fair
	21	8	–	–	–	–	fair
	22	8	–	–	–	–	poor
	23	8	–	–	–	–	poor
	24	9	–	–	–	–	poor
	25	8	–	–	–	–	fair
	26	2	–	–	–	–	poor
	27	8	–	–	–	–	poor
	29	3	2	2	10	–	fair
	30	8	–	2	12	1	poor
May	1	7	–	2	14	–	fair
	2	8	–	2	4	–	poor
	4	10	–	1	1	1	poor

1898		Time	New Grs.	Total Grs.	Total Spots	Fac. Grs.	Def.
June	7	10	1	1	3	–	poor
	9	7	1	2	5	–	poor
	10	10	–	2	16	1	good
	11	8	1	3	25	1	v.good
	12	7	–	2	12	–	fair
	13	10	–	1	17	3	fair
	14	8	1	2	25	2	good
	15	4	1	2	9	–	fair
	16	10	–	1	2	–	poor
	17	8	1	2	5	3	good
	18	7	1	3	9	3	good
	19	7	–	2	3	2	good
	20	8	–	2	3	1	fair
	21	7	–	2	5	1	fair
	22	7	–	2	8	–	fair
	24	9	1	2	5	2	fair
	25	12	–	2	14		poor
	27	7	–	2	14	2	good
	28	8	–	2	10	3	fair
	29	4	2	2	6	3	fair
	30	10	–	2	8	1	poor
	31	7	2	3	14	3	fair
June	1	7		3	16	2	good
	2	6	–	3	6	1	fair
	3	7	–	3	15	2	good
	4	7	–	2	2	3	fair
	5	4	1	3	8	2	fair
	6	7	–	2	13	2	fair
	7	7	–	1	7	3	fair
	8	7	–	1	1	1	poor
	9	7	–	1	1	2	fair
	10	7	–	1	1	1	fair
	11	7	–	–	–	1	poor
	12	8	–	–	–	2	fair
	13	7	–	–	–	2	fair
	14	7	1	1	2	–	poor
	15	8	–	1	5	3	fair
	16	9	1	2	6	1	poor
	17	9	–	1	6	–	poor
	18	8		2	24	1	fair
	19	9	–	1	4	–	poor
	20	8	1	1	1	–	poor
	21	6		1	2	1	fair
	22	7	–	1	4	2	good
	23	7	–	1	1	2	poor
	24	7	–	1	1	2	fair
	25	7	–	1	1	1	fair
	26	7	1	2	7	1	fair
	27	7	1	3	8	1	fair
	28	7	–	3	8	1	poor
	29	7		2	3	1	fair
	30	7		1	2	2	fair

*2½-inch refractor.

MEASURES OF THE FIFTH SATELLITE OF *JUPITER*,

MADE WITH THE 24-INCH REFRACTOR OF THE LOWELL OBSERVATORY,

By T. J. J. SEE.

The following are a few measures of the Fifth Satellite of *Jupiter* attempted at the request of Professor Barnard. As the telescope during these hours of the night was generally used by Mr. Douglass in his work on the other satellites, only a short time was available for measurement of the Fifth, which is always difficult in an instrument of this size. A screen of yellow mica was used to cut off the light of *Jupiter*, and under a steady black sky the satellite appeared quite distinct, and just like a small star of $14^m.5$. However, desultory measures like these can hardly be so accurate as might be expected in work of a more systematic character, and I have indicated this uncertainty by the remarks appended to the observations. The time is seven hours slow of Greenwich, or what is known as Mountain Time.

Measures of the Fifth Satellite of *Jupiter*.

t		θ_0	ρ_0
	h m	°	″
1898 April 18	12 49.5	287.2	41.10 (1)
22	13 10.0	289.5	49.03 (2)
	13 20.0	289.2	53.51 (3)
23	8 33.0	114.5	51.37 (4)
	12 47.5	287.3	52.54 (5)

Notes: (1) Like a small star, magnitude 14.8: quite distinct, but the central wire behind the screen is seen with difficulty. (2) and (3) Fairly good measures, magnitude 14.5. (4) At first quite distinct, but afterwards very difficult. [This distance appears to be abnormally large.] (5) Fairly well seen, and measures satisfactory.

Lowell Observatory, Flagstaff, Arizona, 1898 *June* 16.

COMET *c* 1898.

In addition to the observations communicated in *A.J.* 438, the following additional positions obtained at the Lick Observatory have been telegraphically received.

1898 Gr. M.T.	α	δ	Observer
	h m s	° ′ ″	
June 13.7583	16 18 5.0	−26 31 48	Coddington
13.7876	16 17 58.4	−26 33 3	Tucker (Merid. Circle)

Three sets of elements have been telegraphically communicated, as follows:

Elements.

$$T = 1898 \text{ Sept. } 10.31 \text{ Gr. M.T.}$$

$$\left.\begin{aligned}\omega &= 229^\circ\ 28'\\ \Omega &= \ \ 73\ \ 59\\ i &= \ \ 71\ \ 18\end{aligned}\right\}1898.0$$

$$q = 1.7685$$

Ephemeris for Greenwich Midnight.

	α	δ	Br.
	h m s	° ′	
1898 June 20.5	15 54 32	−30 41	1.07
24.5	40 20	32 59	
28.5	26 24	35 7	
July 2.5	15 12 52	−37 5	1.05

Computed by Messrs. Hussey and Coddington from observations on June 11, 13 and 15. They also send by mail the following particulars:

"This comet was discovered by Mr. Coddington, June 11, 1898, on a photographic plate taken by him with the Crocker Photographic Telescope on the evening of June 9, 1898. Owing to changes that were being made in his dark room this plate was not developed until June 11. On developing the plate a strong trail was found. The region was at once examined with the 12-inch telescope, and an observation of the comet made by Professor Hussey."

Elements.

$$T = 1898 \text{ Sept. } 8.36 \text{ Gr. M.T.}$$

$$\left.\begin{aligned}\omega &= 227^\circ\ 40'\\ \Omega &= \ \ 73\ \ 58\\ i &= \ \ 71\ \ 47\end{aligned}\right\}1898.0$$

$$q = 1.8003$$

Ephemeris for Greenwich Midnight.

	α	δ	Br.
	h m s	° ′	
1898 June 20.5	15 54 40	−30 40	1.06
24.5	40 36	32 57	
28.5	26 44	35 4	
July 2.5	15 13 24	−37 1	1.04

Computed by Mr. Crawford from observations on June 11, 12 and 13.

Elements.

$$T = \text{Aug. } 4.44 \text{ Gr. M.T.}$$

$$\left.\begin{aligned}\omega &= 206^\circ\ \ 9'\\ \Omega &= \ \ 73\ \ 59\\ i &= \ \ 76\ \ 48\end{aligned}\right\}1898.0$$

$$q = 2.0821$$

Ephemeris for Greenwich Midnight.

	α	δ	Br.
	h m s	° ′	
1898 June 19.5	15 58 24	−30 2	0.99
23.5	44 56	32 16	
27.5	31 48	34 19	
July 1.5	15 19 24	−36 10	0.89

Computed by Mr. Berberich from observations on June 11, 13 and 15.

COMET *e* 1898.

Prof. KEELER has telegraphed the discovery of a faint comet by PERRINE, on June 14; and the following positions observed at the Lick Observatory:

1898 Gr. M.T.	α	δ	Observer
	h m s	° ′ ″	
June 14.9740	3 29 1.0	+58 35 25	Perrine
15.9296	3 34 57.7	58 24 2	Perrine
16.9376	3 41 11.9	+58 10 49	Perrine

The following elements and ephemeris were computed by Messrs. PERRINE and AITKEN from the above observations:

ELEMENTS.

T = 1898 Aug. 17.40 Gr. M.T.

$$\left.\begin{aligned}\omega &= 196^\circ\ 46'\\ \Omega &= 260\ \ 6\\ i &= 69\ 42\end{aligned}\right\}1898.0$$

q = 0.7418

EPHEMERIS FOR GREENWICH MIDNIGHT.

	α	δ	Br.
	h m s	° ′	
1898 June 20.5	4 2 52	+57 15	1.18
24.5	4 26 24	+55 56	
28.5	4 48 48	+54 20	
July 2.5	5 10 0	+52 27	1.72

Dr. LEUSCHNER has telegraphed the following elements and ephemeris, computed by Messrs. CRAWFORD and PALMER of the Students' Observatory, University of California, from observations on June 14, 15 and 16:

ELEMENTS.

T = 1898 Aug. 1.13 Gr. M.T.

$$\left.\begin{aligned}\omega &= 242^\circ\ 4'\\ \Omega &= 249\ 25\\ i &= 72\ 53\end{aligned}\right\}1898.0$$

q = 0.2129

EPHEMERIS FOR GREENWICH MIDNIGHT.

	α	δ	Br.
	h m s	° ′	
1898 June 20.5	4 3 40	+57 13	1.33
24.5	4 28 44	55 47	
28.5	4 53 36	53 55	
July 2.5	5 17 56	+51 33	2.79

COMET *f* 1898 = WOLF'S PERIODIC COMET, 1884 III, 1891 II.

Prof. KEELER has telegraphed that WOLF's comet was discovered by Prof. HUSSEY, on June 16, in the following position:

1898 Gr. M.T.	α	δ
June 16.9666	2h 16m 18s.9 ,	+19° 42′ 44″

The correction to THRAEN's finding ephemeris is therefore practically insignificant, according to this observation. The continuation of this ephemeris, from *A.N.* 3481, is therefore given below.

EPHEMERIS FOR BERLIN MIDNIGHT.

	α	δ
	h m s	° ′
1898 July 1.5	2 59 39	+20 11
5.5	3 11 32	+20 10
1898 July 9.5	3 23 22	+20 5
13.5	35 7	19 55
17.5	46 44	19 41
21.5	3 58 15	19 23
25.5	4 9 35	19 0
29.5	20 45	18 33
Aug. 2.5	31 43	18 3
6.5	42 28	17 27
10.5	4 52 59	16 49
14.5	5 3 13	16 6
18.5	13 12	15 20
22.5	22 52	14 29
26.5	32 13	13 36
30.5	41 13	12 39
Sept. 3.5	5 49 32	+11 40

COMET *g* 1898.

Prof. KREUTZ has telegraphed the discovery of a comet by GIACOBINI, on June 18; and the following positions observed at the Nice Observatory:

1898 June 18.521 Gr. M.T.	α = 20h 36m 28s ,	δ = −21° 14′ 0″
19.5079	20 26 40.8 ,	−21 27 6

Another despatch received by Mr. RITCHIE from Kiel communicates the following elements and ephemeris, the name of the computer not being stated. Derived as a rough approximation from observations of June 19, 20 and 21.

ELEMENTS.

T = 1898 July 6.23 Gr. M.T.

$$\left.\begin{array}{l}\omega = 7\ 36 \\ \Omega = 278\ 31 \\ i = 166\ 45\end{array}\right\}1898.0$$

q = 1.5864

EPHEMERIS FOR GREENWICH MIDNIGHT.

	α	δ	Br.
	h m s	° ′	
1898 June 29.5	18 5 16	−21 35	1.35
July 3.5	17 7 32	19 27	
7.5	16 19 48	16 16	
11.5	15 13 16	−14 10	0.79

During the unusual and unavoidable interval of delay in the issue of the present number, extensions of the ephemerides of the various comets now visible have been anxiously looked for and awaited from some of the astronomers who usually take care to provide them for the use of observers; but none have been received; nor has the Editor found it possible to supply this unfortunate deficiency. It is earnestly to be hoped that the thoughtful foresight of some of the computers and observers who are interested in the matter will prevent in the future a similar deficiency.—ED.

OBSERVATIONS OF COMETS *c* AND *e* 1898,

MADE AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA, WITH THE 12-INCH EQUATORIAL.

BY C. D. PERRINE.

1898 Mt. Hamilton M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			COMET *c* 1898 (CODDINGTON).					
	h m s		m s	′ ″	h m s	° ′ ″		
June 12 14 23 52	1	*d*10 , 8	−0 6.06	+1 8.4	16 20 51.23	−26 0 39.1	9.618	0.825
			COMET *e* 1898 (PERRINE).					
June 14 15 15 59	2	*d* 4 , 3	−0 26.84	−3 15.6	3 29 0.99	+58 35 22.3	*n*9.949	0.290
15 14 12 6	4	18 , 8	+1 8.32	−1 11.4	3 34 57.67	+58 23 58.6	*n*9.906	9.230
16 14 23 33	5	18 , 8	+0 26.00	+6 44.6	3 41 11.86	+58 10 49.1	*n*9.911	9.230

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 20 53.10	+4.19	−26 1 35.3	−12.5	Cordoba G.C. 22270
2	3 29 26.51	+1.32	+58 38 36.2	+ 1.7	Micrometer-comparison with *3
3	3 31 28.32	+1.32	+58 40 46.1	+ 1.7	Helsingfors–Gotha A.G. 3120
4	3 33 47.99	+1.36	+58 25 8.4	+ 1.6	Helsingfors–Gotha A.G. 3151
5	3 40 44.46	+1.40	+58 4 2.9	+ 1.6	Micrometer-comparison with *6
6	3 37 37.68	+1.40	+57 59 38.2	+ 1.6	Helsingfors–Gotha A.G. 3174

NOTES.

d indicates that Δα was measured directly with the micrometer.

June 14. Discovery measures made in dawn; not time to make complete measure.

Comet *e* is a little fainter than Comet *b* is at present, estimated about $10\frac{1}{2}$M. Comet is about 1′ or $1\frac{1}{2}$′ in diameter, and has a central condensation, but no nucleus.

Mt. Hamilton, Cal., 1898 *June* 16.

OBSERVATIONS OF COMET *c* 1898, (*CODDINGTON*).

MADE AT THE SAYRE OBSERVATORY, SOUTH BETHLEHEM, PA.,

BY JOHN H. OGBURN.

1898 Bethlehem M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s	° ′ ″		
June 14 11 14 56	1	5	−0 11.17	−7 12.4	16 14 55.28	−27 6 40.0	8.871	0.910
15 10 1 10	2	7 , 9	−0 23.33	+5 14.5	16 11 38.92	−27 42 21.8	*n*8.859	0.912

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 15 2.23	+4.22	−26 59 14.4	−13.2	Gould, Cordoba Zone-Catal. 16 962
2	16 11 58.01	+4.24	−27 47 22.8	−13.5	½ (2 Gould 22077 + Yarnall 6848)

ELEMENTS AND EPHEMERIDES OF COMETS *c* 1898 (*CODDINGTON*) AND *d* 1898, (*PERRINE*).*

BY R. T. CRAWFORD.

From Mount Hamilton observations kindly telegraphed to the Students' Observatory by Director JAMES E. KEELER, I have computed the following orbits of Comet *c* 1898 (CODDINGTON), and Comet *d* 1898 (PERRINE), the latter with the assistance of Mr. H. K. PALMER, graduate student:

COMET *c* 1898 (CODDINGTON).

OBSERVATIONS.

1898 Gr. M.T.	App. α	App. δ	Observer
	h m s	° ′ ″	
June 11.7220	16 24 55.9	−25 14 20	Hussey
12.7288	16 21 31.1	−25 52 43	Coddington
13.7583	16 18 5.0	−26 31 48	Coddington

ELEMENTS.

$$T = \text{Sept. } 8.36349 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} i &= 71^\circ\ 47'\ 19'' \\ \Omega &= 73\ 58\ 24 \\ \omega &= 227\ 40\ 10 \\ \pi &= 301\ 38\ 34 \end{aligned}\right\}\ 1898.0$$

$$\log q = 0.255338$$

$$\text{O—C:}\quad d\lambda \cos\beta = +3''.0\quad ,\quad d\beta = +1''.1.$$

CONSTANTS FOR THE EQUATOR OF 1898.0.

$$x = [9.865980] \sin(\ 5^\circ\ 4'\ 56'' + v) \sec^2 \tfrac{1}{2} v$$
$$y = [0.224295] \sin(336\ 23\ 44 + v) \sec^2 \tfrac{1}{2} v$$
$$z = [0.247996] \sin(250\ 33\ 51 + v) \sec^2 \tfrac{1}{2} v$$

An approximate comparison of these results with two observations by Professor LEUSCHNER, June 16th and 17th, reveals no appreciable corrections to the ephemeris.

COMET *d* 1898 (PERRINE).

OBSERVATIONS.

1898 Gr. M.T.	App. α	App. δ	Observer
	h m s	° ′ ″	
June 14.9740	3 29 1.0	+58 35 25	Perrine
	3 34 57.7	+58 24 2	Perrine
	3 41 11.9	+58 10 49	Perrine

ELEMENTS.

$$T = \text{Aug. } 1.14561 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} i &= 72^\circ\ 52'\ 39'' \\ \Omega &= 249\ 25\ 7 \\ \omega &= 242\ 4\ 24 \\ \pi &= 131\ 29\ 31 \end{aligned}\right\}\ 1898.0$$

$$\log q = 9.328168$$

$$\text{O—C:}\quad d\lambda \cos\beta = +2''.5\quad ,\quad d\beta = -2''.7.$$

CONSTANTS FOR THE EQUATOR OF 1898.0.

$$x = [8.977723] \sin(190^\circ\ 5'\ 33'' + v) \sec^2 \tfrac{1}{2} v$$
$$y = [9.320060] \sin(123\ 7\ 15 + v) \sec^2 \tfrac{1}{2} v$$
$$z = [9.289670] \sin(218\ 2\ 57 + v) \sec^2 \tfrac{1}{2} v$$

University of California, Students' Observatory, 1898 June 18.

FILAR-MICROMETER OBSERVATIONS OF COMET *c* 1898 (*CODDINGTON*).

BY E. E. BARNARD.

90th Meridian Time 1898	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ
h m s			m s	′ ″	h m s	° ′
June 13 10 36 15	1	6 , 3	−0 11.06	+4 36.2	16 18 18.6	−26 29.6
14 9 25 47	2	4 , 8	−0 3.20	−5 53.9	16 15 3.5	−27 5.1

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′	″	
1	16 18 25.5	+1.22	−26 34.1	−12.8	Cordoba DM. −26 11329
2	16 15 2.1	+1.22	−26 59.0	−13.2	Cordoba DM −26 11292

The comet is about 8^M or 9^M, with a strong, almost stellar condensation, and a short brush of tail to the north. The positions are direct measures with the micrometer of the 40-inch. We have not yet accurate catalogues for the positions covering the region of observation.

*These elements were also telegraphed on June 17th and June 18th.

REDISCOVERY OF WOLF'S PERIODICAL COMET, *f* 1898.

By WILLIAM J. HUSSEY.

Yesterday morning I rediscovered this periodical comet with the 36-inch refractor very close to the place given by Thraen's ephemeris in the *A.N.* 3481. This morning I observed it with the 12-inch telescope, and found it an easy object with this instrument. The position at the time of rediscovery is given by the following observation:

Mt. Hamilton M.T.	⁎	No. Comp.	☄ − ⁎ $\Delta\alpha$	☄ − ⁎ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
1898 June 16 15h 5m 21s	1	6 . 6	+1m 25.77s	+3′ 13.6″	2h 16m 18.91s	+19° 42′ 44.1″	n9.691	0.668

Mean Place for 1898.0 of Comparison-Star.

⁎	α	Red. to app. place	δ	Red. to app. place	Authority
1	2h 14m 51.47s	+1.67s	+19° 39′ 22.1″	+8.4″	Auwers, Berlin A.G. Catal. 646

Lick Observatory, Mt. Hamilton, Cal., 1898 *June* 18.

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RESEARCHES ON THE SYSTEM OF *PROCYON*.

By T. J. J. SEE.

The discovery of the companion of *Procyon*, more than half a century after its existence had been suspected by BESSEL, must be considered a notable achievement of our time. Professor SCHAEBERLE's beautiful optical discovery is not only important in itself, as disclosing a binary system of high interest, but also in giving data, which, in combination with the observations of the relative position of *Procyon* for the last forty-seven years, furnish at once an accurate knowledge of the system. We are thus unexpectedly placed in possession of material which enables us to trace the orbit of what turns out to be the grandest of known binary stars, and to determine the relative masses with a considerable degree of precision. The researches on this dark and hitherto unseen companion are so instructive, that I venture to think an outline of their salient features will not be devoid of interest.

The early investigations of BESSEL on the proper motions of the fixed stars led him to reflect that the assumption of uniform movement on the arc of a great circle, deduced from the laws of undisturbed motion, and universally current since the time of HALLEY, rested on a purely empirical foundation, and consequently was to be admitted in treating of the actual heavens only so long as it satisfied observations. The discovery in 1834 of very sensible irregularities in the motion of *Sirius* produced the conviction that this star is not moving uniformly, but suffers periodic perturbations from some external cause; and nothing was more natural than to assume that the bright object is a part of a binary system, of which only a single component had been disclosed. Six years later he reached a similar conclusion regarding the motion of *Procyon*, though the foundation upon which the second case rested was less satisfactory than the first, and his conclusion was correspondingly cautious. Yet in one of his last letters to HUMBOLDT (cited by WOLF, *Gesch. der Astron.*, p. 743, note), BESSEL expresses himself confidently: "I adhere to the conviction that *Procyon* and *Sirius* form real binary systems, consisting of a visible and an invisible star. There is no reason to suppose luminosity an essential quality of cosmical bodies. The visibility of countless stars is no argument against the invisibility of countless others."

PETERS had investigated the irregular motion of *Sirius* in 1851 and AUWERS in 1862 undertook a critical examination of the motion of *Procyon*. The outcome of his investigation was a decisive confirmation of the suggestion of BESSEL, though the smaller absolute displacements to which *Procyon* is subjected in comparison with the inevitable errors of observation rendered the satisfactory determination of this orbit much more difficult than that of *Sirius*, where the satellite has a greater relative mass, and moves in a larger apparent orbit. Though Dr. AUWERS discussed the meridian observations with all the skill and exhaustiveness characteristic of that distinguished astronomer, and continued the work at intervals till 1871, he was obliged to content himself throughout with the assumption of a circular orbit lying in a plane tangent to the celestial sphere. The period deduced by these profound investigations was 39.972 years. We refer in the conclusion of this paper to the supposed discovery of the companion of *Procyon* at Pulkowa, 1873 March 19, and the similar deceptions reported from other observatories. It now seems clear that all of these objects were spurious, and could have had no connection with the genuine BESSEL companion found by SCHAEBERLE.

The only unsuccessful optical search by a skilled observer which now calls for attention is that made by BURNHAM with the 36-inch refractor of the Lick Observatory, in 1888 and 1890. His records furnish satisfactory proof that the object was then invisible in the most powerful telescope in the world, and are of no small importance in disclosing the character of the orbit. The notes then taken are:

"1888.818. Carefully examined with all powers up to 3300 on the 36-inch, under favorable conditions. Large star single, and no near companion."

"1890.785. Carefully examined with various powers. Nothing nearer than the old companion."

It has been known since the investigations of AUWERS that the motion of the companion is direct, and as SCHAEBERLE found it in angle 318° in 1896, it is clear that the angle at the time of BURNHAM's observations must have been considerable smaller. Since the discovery was made with the same telescope which had formerly been unsuccessful, in the hands of one of the most skillful observers of all time, the presumption is that the distance had increased. We shall see that these conclusions are indicated from another point of view.

In the year 1851 OTTO STRUVE began a series of measures of *Procyon* with respect to neighboring stars, and continued the work with few interruptions for 39 years. The stars chosen were, DM. 5°1738, mag. 9, and DM. 5°1741, mag. 8.8; which STRUVE calls B and C respectively. B precedes and C follows *Procyon* at intervals of some 20 seconds of time; and both are to the north of the bright star. It may be noted that C is a very close double, but this fact does not bear on the present inquiry. As these observations were made with the micrometer in the hands of a most experienced observer, such relative places evidently have much greater accuracy than absolute positions depending on the Meridian Circle. In the present investigation of the orbit I have therefore relied entirely on this work, and on the micrometrical measures of the companion since 1896. BURNHAM saw the advantage of such procedure four years ago, and even discussed it in his paper in the *Astronomy and Astro-physics*, No. 126. But as the companion had not yet been discovered optically, it then seemed useless to attempt to do more than confirm the conclusions drawn from the meridian observations.

In dealing with the orbit of *Procyon*, the method of procedure is substantially as follows: OTTO STRUVE has given (*Annals of the Pulkowa Observatory*, Vol. X) the places of *Procyon* with respect to B and C for many years: these small stars are assumed to be (and are in fact) sensibly fixed in space, and as *Procyon* has a large proper motion of 1″.257 in direction 216°.6, the result is that by taking the origin of coordinates at a convenient (arbitrary) distance from one of these stars, *Procyon* is made to exhibit its variable motion in the sinuous curve traced out by the large star about the uniformly-moving center of gravity of the system. In the table we thus take the region of right-ascension and declination so as to include the positions occupied by *Procyon* during the period of observation. Omitting, in the case of the star B, the constant part 70″, which stands at the head of the column $\Delta\delta_o''$, the declination is seen to vary from 4″.42 to 43″.41; the right-ascension from $22^s + 49''.20$ to $22^s + 19''.28$. It will be understood, of course, that these values of $\Delta\alpha_o''$ and $\Delta\delta_o''$ are reduced to a common epoch (1850.0), and that the arc $\Delta\alpha_o''$ tabulated is reduced to absolute space by the cosine of the declination of *Procyon*. In the case of C, the constant of declination omitted is 25″.48; this value was determined by the criterion that for the whole series of observations the sum of the differences deduced relative to the star B should vanish. This amounts to the same thing as transferring the systems of coordinates for the two stars to a common origin. The right-ascensions were adjusted in like manner. The table exhibits the accordance of observation with the orbit here deduced. Though the errors of observation are quite appreciable, the general trend indicates a remarkable agreement with theory.

Experience in double-star work, where the errors are large in comparison with the quantity measured, has fully demonstrated the superiority of graphical over numerical methods. In the present case the considerable magnitude of some of the errors, especially in $\Delta\alpha_o''$, rendered a purely numerical computation liable to serious objection. I therefore proceeded by graphical methods until a satisfactory orbit was obtained, and then compared the observations with theory.

The elements of the orbit of *Procyon* about the center of gravity of the system were found to be

$$\begin{aligned} P &= 40.0 \text{ years} \\ T &= 1891.0 \\ e &= 0.45 \\ a &= 0''.94 \\ \Omega &= 108^\circ.3 \\ i &= 33^\circ.13 \\ \lambda &= 286^\circ.35 \end{aligned}$$

The elements of the relative orbit of the companion about *Procyon* are

$$\begin{aligned} P &= 40.0 \text{ years} \\ T &= 1891.0 \\ e &= 0.45 \\ a &= 5''.84 \\ \Omega &= 108^\circ.3 \\ i &= 33^\circ.13 \\ \lambda &= 106^\circ.35 \\ n &= +9^\circ.0000 \end{aligned}$$

Apparent orbit:

Length of major axis	=	9″.70
Length of minor axis	=	8″.80
Angle of major axis	=	63°.6
Angle of periastron	=	216°.6
Distance of star from center	=	2″.16

Comparison of Computed with Observed Places.

t	$\Delta\delta_o''$	$\Delta\alpha_o''$	$\Delta\delta_o''-\Delta\delta_c''$	$\Delta\alpha_o''-\Delta\alpha_c''$	$\Delta\delta_o''$	$\Delta\alpha_o''$	$\Delta\delta_o''-\Delta\delta_c''$	$\Delta\alpha_o''-\Delta\alpha_c''$
	Star *B*				Star *C*			
	70″+	22ˢ+			25″.48+	24ˢ.78−		
1851.12	4.42	49.20	+0.42	−0.30	4.12	52.43	+0.12	+2.93
1852.04	5.23	. .	+0.21	. .	4.83	. .	−0.19	. .
1853.26	6.58	47.76	+0.16	−0.13	6.42	47.49	±0.00	−0.70
1854.19	7.54	48.75	+0.03	+1.22	7.35	47.34	−0.16	−0.19
1855.25	8.69	47.65	−0.06	+0.93	8.76	46.93	+0.01	+0.21
1857.22	10.75	44.95	−0.17	−0.23	11.00	45.86	+0.08	+0.68
1859.20	12.92	43.80	−0.16	+0.25	12.89	42.00	−0.19	−1.55
1860.25	14.24	46.78	±0.00	+4.09	14.14	40.84	−0.10	−1.82
1861.25	15.49	43.63	+0.21	+1.78	15.18	40.12	−0.10	−1.73
1862.21	15.94	. .	−0.37	. .	15.95	. .	−0.36	. .
1863.21	17.59	39.73	+0.29	−0.47	17.43	39.90	+0.13	−0.30
1864.24	18.41	40.41	+0.03	+1.09	18.64	39.01	+0.26	−0.31
1866.23	20.46	37.81	+0.08	+0.13	20.32	37.54	−0.06	−0.14
1868.25	22.29	34.96	−0.04	−1.08	22.19	35.38	−0.14	−0.66
1869.22	23.34	35.63	+0.01	+0.50	23.51	35.15	+0.21	+0.02
1870.22	24.26	34.33	+0.01	+0.03	24.36	35.13	+0.11	+0.83
1873.22	26.40	. .	−0.67	. .	26.94	. .	−0.13	. .
1874.17	27.83	30.90	−0.13	−0.21	27.94	30.57	−0.01	−0.54
1876.23	29.13	29.33	−0.62	−0.22	29.45	29.28	−0.30	−0.27
1877.19	30.73	27.95	+0.05	−0.83	30.57	27.74	−0.11	−1.04
1878.23	31.37	28.52	−0.23	+0.52	31.38	30.09	−0.22	+2.09
1879.18	32.36	26.35	−0.12	−0.93	32.32	27.61	−0.16	+0.33
1881.25	34.52	25.09	+0.14	−0.69	34.42	26.00	+0.04	+0.22
1882.25	35.12	24.40	−0.16	−0.67	35.01	25.11	−0.27	+0.04
1884.22	37.08	. .	+0.04	. .	36.96	. .	−0.08	. .
1886.21	38.70	20.83	−0.12	−1.61	38.88	21.89	+0.06	−0.58
1887.22	39.96	21.97	+0.18	+0.12	39.92	24.36	+0.14	+2.51
1889.21	42.20	20.43	+0.48	−0.25	42.45	22.19	+0.73	+1.51
1890.10	43.41	19.28	+0.80	−0.94	43.79	20.38	+1.18	+0.16

When carefully plotted it is found that the irregularities in the motion of *Procyon* are as represented on the accompanying plate, which shows also the orbit of *Procyon* about the center of gravity, and the relative orbit of the companion about the large star. The part of the plate designated "Absolute path in space," shows the curve traced by *Procyon* in the general direction 216°.6. For convenience of inspection the observations of *Procyon* relative to the star *B* are denoted by the larger, those relative to *C* by the smaller, points. On examining the motion from 1851 to 1860 it is easy to see that *Procyon* rapidly departed from the line traversed by the center of gravity, and this sudden bend indicates a moderately high eccentricity; the upper part of the curve shows how it again rapidly approached this line in completing the revolution. Though it is not probable that the major axis points exactly in the direction of proper motion, there is no evidence of asymmetry in the arrangement of the orbit relative to the path traversed by the center of gravity, and accordingly that line is assumed to coincide with the real major axis. The eccentricity here adopted as the result of successive approximations is near the most probable value that can be chosen for the orbit of a double star, and besides being thus inherently probable is the only value consistent with the observations now available. It is very unlikely that the eccentricity is in error by more than 0.05. The comparatively slow motion of the companion since its discovery indicates that the orbit must be moderately eccentric; and as a closer examination of the case shows that the inclination is small, we are left with no alternative but the one here adopted. The elements explain all the observations in a satisfactory manner, and must, we think, be accounted a fair approximation to the true orbit. As the declinations are necessarily more accurate than the right-ascensions, I have thought it proper to give an additional curve representing the "Perturbation in Declination." In this diagram the horizontal axis represents the time, the vertical axis the declination; and with an equal scale of one second per year, the perturbation in declination is made very apparent. It is easily seen that the present orbit represents the irregularity almost perfectly. The desirability of combining two diagrams in one plate without entangling the curves induced me in the present case to shift the origin to the left (without vertical displacement), so that the declinations are

the same in the two diagrams. This facilitates the study of the perturbations, and as the time does not directly enter into the construction of the "Absolute path in space," there is no occasion for confusion. Moreover, the few epochs indicated along the line of the "Absolute path," will enable the reader to follow the principal phenomena of that diagram without difficulty.

The positions occupied by the center of gravity at the different epochs are denoted by small intersections of the line of proper motion. The corresponding computed places of *Procyon* lie on the sinuous curve at points indicated by small crosses.

The following is a comparison of these elements with the observations of the companion made with the micrometer.

t	θ_o	θ_c	ρ_o	ρ_c	$\theta_o-\theta_c$	$\rho_o-\rho_c$	n	Observers
	°	°	″	″	°	″		
1888.818	. .	157.7	. .	3.01	. .	. .	1	Burnham } nothing
1890.785	. .	211.0	. .	2.62	. .	. .	1	Burnham } seen
1896.870	318.8	315.2	4.59	4.56	+3.6	+0.03	1	Schaeberle
1896.947	322.1	315.8	4.90	4.57	+6.3	+0.33	2	Aitken
1897.160	319.8	317.6	4.65	4.60	+2.2	+0.05	3	Hussey
1897.821	324.4	323.3	4.66	4.68	+1.1	−0.02	7–6	Schaeberle
1897.880	323.8	323.8	4.70	4.69	±0.0	+0.01	3	Aitken
1898.173	326.9	326.2	4.61	4.79	+0.7	−0.18	4	See
1898.173	327.7	326.2	4.82	4.79	+1.5	+0.03	4	Boothroyd
1898.213	326.0	326.5	4.83	4.80	−0.5	+0.03	7–6	Barnard
1898.236	326.0	326.7	4.26	4.81	−0.7	−0.55	3	Lewis

Ephemeris.

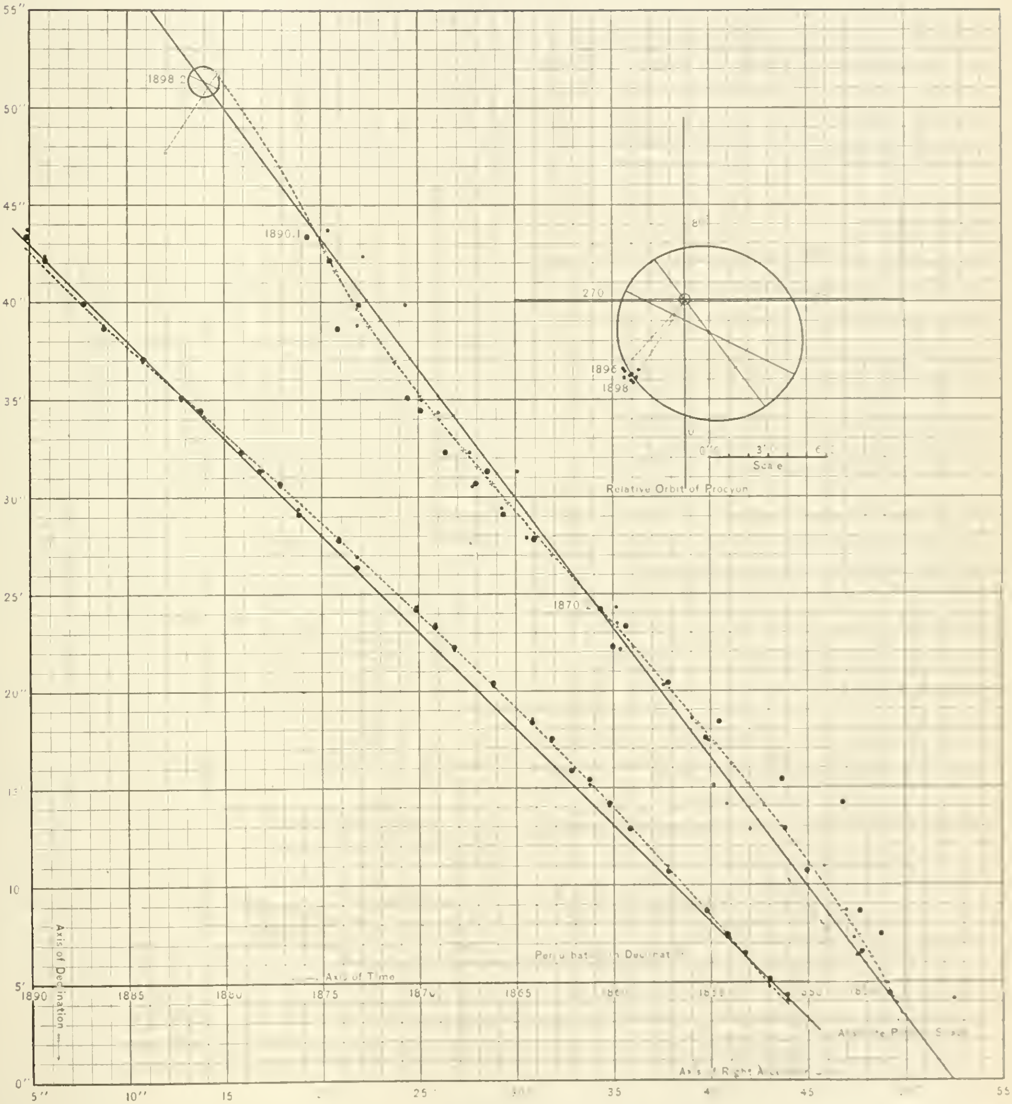
t	θ_c	ρ_c	t	θ_c	ρ_c
	°	″		°	″
1899.20	334.0	5.00	1904.20	4.9	6.06
1900.20	341.0	5.26	1905.20	10.0	6.23
1901.20	347.3	5.45	1906.20	15.1	6.41
1902.20	353.3	5.66	1907.20	19.9	6.54
1903.20	359.3	5.88	1908.20	24.7	6.70

It follows from these results that the distance will steadily increase for a number of years, and that the companion will eventually become quite easy. At the time of Burnham's searches, however, it was beyond the reach of any existing telescope, and hence his failure to see it is not surprising. Yet even the negative observation is valuable in confirming the orbit now deduced.

At the time of Otto Struve's searches in 1873 and 1874 the companion was comparatively wide (6″.9), though from its known faintness we may now feel sure that it would have been invisible in the 15-inch telescope in a climate such as that of Pulkowa. The failure to see it at Washington at that time must be explained by similar adverse climatic conditions, or by the inexperience of the American observers who made the examination. It ought to have been easily visible in a 26-inch telescope on a night when the spurious image of *Procyon* is contracted to a small point, and the fringes are quiescent. Here at Flagstaff it is possible to see objects much more difficult with the Lowell telescope of 24-inch aperture.

Otto Struve's deception and announcement of the companion at a distance of ten seconds is said to have arisen from a ghost in the Mertz 15-inch object-glass, which vanished when the telescope was reversed. Since the mounting of the new Clark refractor, the companion has been too close to be easily seen at Pulkowa, even with a 30-inch aperture. But now it ought to be visible in that instrument, and we may expect it to receive adequate attention hereafter. While the present orbit will doubtless need some correction as soon as the orbital motion develops, it is difficult to see how its essential nature can be materially changed. The present state of the observations would not warrant any further attempts at refinement. Taking the present distance to be 4″.80, the masses are found to be in the ratio of exactly 1 : 5. This value does not seem liable to an error of more than ten per cent., and is probably as exact as that of any known system except *α Centauri*. Using Dr. Elkin's parallax of 0″.266 ± 0″.047, determined with the Heliometer, we find the major semi-axis of the orbit of *Procyon* about the center of gravity to have a length of 3.534 astronomical units; and as the semi-axis of the relative orbits is six times larger, or 21.2, we see that the dimensions of the orbit of the companion slightly surpass those of the planet *Uranus*.

The combined mass of the system is found to be 5.955 that of the sun and earth; and as the companion is one-fifth as massive as the large star, we see that it has a mass equal to 0.99, or almost exactly the same as that of our sun. The system is thus the most magnificent which astronomical observation has yet disclosed. Assuming the magnitudes of *Procyon* and *Sirius* to be respectively 0.5 and −1.4, we find that the former gives only one-thirteenth as much light as the latter. *Sirius* itself is found by the best estimates to radiate about forty times more light than the sun, and hence *Procyon* gives only about three times



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this quantity. Thus, although the system is very massive, it is not very brilliant. At best the large central star shines with a very moderate luminosity, while the purple companion is evidently quite obscure. For, assuming that the companion is twelve magnitudes fainter than the large star (it must be at least that faint), we find that it radiates less than one sixty-thousandth as much light as *Procyon*, or one twenty-thousandth as much light as our sun, which has an equal mass.

The detection of this companion from irregularities in the proper motion of *Procyon*, amounting in the maximum to but little more than a second of arc, before any account was taken of latitude-variation or the other minute corrections now applied to meridian observations, furnishes an impressive illustration of the value of precise observations and their thorough analysis. It is not to be doubted that other bright stars will be found to be similarly perturbed as soon as their motions are critically studied. STRUVE's work on *Procyon* is a good example of how such stars may be advantageously investigated by the practical astronomer who uses an equatorial telescope of moderate size.

In closing this paper it is proper to acknowledge the assistance which Mr. BOOTHROYD has rendered in the computations, and the interest he has shown in the investigation of this remarkable system.

Lowell Observatory, Flagstaff, Ariz., 1898 *June* 24.

THEORY OF THE MOTION OF THE SPOTS ON *JUPITER*.

BY E. J. WILCZYNSKI.

In my paper on the causes of the sunspot period (¹) I have published an investigation which has an important application not noticed at the time. It is not my intention to discuss this matter in full in the present paper, as that would require much more analytical and numerical work than the time I now have at my disposal permits. It suffices to give a general theory of the phenomena involved, leaving the details for the future.

Mr. O. LOHSE has recently published in *A.N.* 3490 the results of his observations of the rotatory velocity of *Jupiter's* great red spot. He finds it impossible to reconcile the observed facts with the assumption that this spot rotates with a constant velocity. He finds the velocity of rotation to be an alternately increasing and decreasing function of the time. Other observers, among whom I will only quote HOUGH, (²) have made similar remarks for other spots, all of which seem to move with a variable velocity of rotation, although I believe LOHSE's observations to be the first which give any considerable information about the law of the change.

Now, in my paper, I have shown for a different purpose how such variations in this quantity can occur. The reasoning there employed can be applied immediately to *Jupiter*, as well as to the *Sun*. Nevertheless the case which was there treated in *extenso*, namely, that of an incompressible fluid, while admitting of immediate generalization for other cases, is certainly not the case occurring in Nature. We will, therefore, not confining ourselves to the case of *Jupiter*, make assumptions which are much more general. The different assumptions which can be made do not at all affect the main result, but only change the results in minor details.

(¹) *Astrophysical Journal*, Vol. VII, No. 2.

(²) HOUGH, *A.N.* 3354.

Let us then suppose that *Jupiter* has a solid, approximately spherical nucleus, and is surrounded by a viscous, gaseous atmosphere of uniform temperature. The points of the atmosphere are supposed to describe circular orbits parallel to the plane of *Jupiter's* equator, whose centers are situated upon the prolongation of *Jupiter's* axis of rotation, the axis of z. According to a theorem demonstrated in my thesis (¹), the velocity of rotation ω must be that of the solid nucleus for all points of the atmosphere lying within the cylinder tangent to the nucleus at its equator. For points outside of this *bounding cylinder*, ω may be any function of r, the distance from the axis of rotation.

In my thesis the following equations are demonstrated (²):

$$-\omega^2 r = f\frac{\partial V}{\partial r} - \frac{1}{\rho}\frac{\partial p}{\partial r}, \quad 0 = f\frac{\partial V}{\partial z} - \frac{1}{\rho}\frac{\partial p}{\partial z} \tag{1}$$

$$\frac{\partial \omega}{\partial t} = \frac{k}{\rho}\left(\frac{\partial^2 \omega}{\partial r^2} + \frac{3}{r}\frac{\partial \omega}{\partial r}\right) + \frac{\partial k}{\partial r}\frac{\partial \omega}{\partial r} \tag{2}$$

in which ρ, p, k, V, denote respectively the density, pressure, coefficient of viscosity, and potential for the point whose coordinates are x, y and z; r denotes $\sqrt{x^2+y^2}$, the distance from the axis of rotation.

Inside of the bounding cylinder just mentioned ω has everywhere the same value. Therefore, according to (2) $\frac{\partial \omega}{\partial t} = 0$; *i.e.*, if the motion is strictly circular, for points within the bounding cylinder it is also uniform.

But outside of this cylinder ω is a function of r, and also of t as equation (2) shows.

Suppose that the atmosphere consists of the same elements everywhere, the temperature being everywhere the same. Then k, which according to a law of gases, experi-

(¹) *Hydrodynamische Untersuchungen mit Anwendungen auf die Theorie der Sonnenrotation.* Berlin, 1897, p. 24.

(²) p. 7.

mentally confirmed, does not depend upon the pressure p, is also everywhere the same. Hence $\frac{\partial k}{\partial r} = 0$, and we have more simply

$$\frac{\partial \omega}{\partial t} = \frac{k}{\rho}\left(\frac{\partial^2 \omega}{\partial r^2} + \frac{3}{r}\frac{\partial \omega}{\partial r}\right). \tag{3}$$

In my former paper I assumed $\rho = \text{const.}$, which is the case of an incompressible fluid. At present ρ may be more generally a function of r and z, but not of t, so that the density in any one point of the atmosphere is in our investigation supposed to remain constant for all times.

Let us attempt to solve (3) by putting

$$\omega = e^{t\varphi + \psi} \tag{4}$$

where φ and ψ are functions of r and z, to be so determined that this expression becomes a solution of (3). Substituting (4) for ω in (3), we find

$$\varphi = \frac{k}{\rho}\left[t\frac{\partial^2 \varphi}{\partial r^2} + \frac{\partial^2 \psi}{\partial r^2} + \left\{t\frac{\partial \varphi}{\partial r} + \frac{\partial \psi}{\partial r}\right\}^2 + \frac{3}{r}\left\{t\frac{\partial \varphi}{\partial r} + \frac{\partial \psi}{\partial r}\right\}\right]$$

Since this must hold for all values of t, we find

$$\left\{\begin{aligned} \varphi &= \frac{k}{\rho}\left[\frac{\partial^2 \psi}{\partial r^2} + \left(\frac{\partial \psi}{\partial r}\right)^2 + \frac{3}{r}\frac{\partial \psi}{\partial r}\right] \\ 0 &= \frac{\partial^2 \varphi}{\partial r^2} + 2\frac{\partial \varphi}{\partial r}\frac{\partial \psi}{\partial r} + \frac{3}{r}\frac{\partial \varphi}{\partial r} \\ 0 &= \left(\frac{\partial \varphi}{\partial r}\right)^2 \end{aligned}\right. \tag{5}$$

The last equation shows that φ can be a function of z only $= \varphi(z)$. It may be *any* function of z, and the second equation will then also be verified. As condition for ψ we find the first equation (5),

$$\frac{\partial^2 \psi}{\partial r^2} + \left(\frac{\partial \psi}{\partial r}\right)^2 + \frac{3}{r}\frac{\partial \psi}{\partial r} = \frac{\rho}{k}\varphi(z) \tag{6}$$

or putting $\psi = \log u$,

$$\frac{\partial^2 u}{\partial r^2} + \frac{3}{r}\frac{\partial u}{\partial r} - \frac{\rho}{k}\varphi(z)\,u = 0 \tag{7}$$

If, therefore, $\varphi(z)$ is any function of z, and then u is found from the equation (7), which involves two more arbitrary functions of z,

$$\omega = u\,e^{\varphi t}$$

is a solution of (3). By making $\varphi(z)$ successively equal to different arbitrary functions $\varphi_1(z)$, $\varphi_2(z)$, etc., and finding the general solution of the corresponding equation (7) *i.e.*, after φ has been put equal to φ_1, φ_2, etc., we can find an infinity of such solutions, and their sum

$$\omega = \Sigma u_k\, e^{\varphi_k t}$$

is also a solution of (3).

Equation (7) admits the singular point $r = 0$, and according to Fuchs's theory of linear differential equations the determining fundamental equation for this point is

$$s(s-1) + 3s = 0,$$

with the roots $s = 0$ and $s = -2$, which proves that the two fundamental solutions of (7) have the form

$$\left\{\begin{aligned} u_1 &= c_0 + c_1 r + c_2 r^2 + \ldots \\ u_2 &= \frac{d_{-2}}{r^2} + \frac{d_{-1}}{r} + d_0 + d_1 r + d_2 r^2 + \ldots \end{aligned}\right.$$

The second solution is of no present interest to us, since it becomes infinite for $r = 0$. The first can be directly expressed as a definite integral. If we denote by q^2,

$$q^2 = \frac{\rho}{k}\varphi(z)\ ,\quad q_i^2 = \frac{\rho}{k}\varphi_i(z) \tag{8}$$

this solution of (7), will be as is found in the classical text-books,

$$u_i = \int_0^{\pi} \tfrac{1}{2}\left(e^{q_i r\cos\lambda} + e^{-q_i r\cos\lambda}\right)\sin^2\lambda\, d\lambda \tag{9}$$

For ω we will then have

$$\omega = \Sigma a_i u_i e^{t\varphi_i} \tag{10}$$

where a_i is an arbitrary function of z, as is also φ_i.

The functions φ_i may be complex quantities, as may also u_i, so that the real part of (10), being equated to ω, will consist of such terms as

$$A\,u\,e^{-c^2 t}\cos\lambda t \quad \text{and} \quad B\,u\,e^{-c^2 t}\sin\lambda t \tag{11}$$

where A, B, c and λ are real functions of z, and u is a function of r.

This proves that periodic variations in ω are to be expected, such as Mr. Lohse has observed. But λ, and therefore the period of such a term, depends only on z, not on r, *i.e. for all points of a plane perpendicular to the axis of rotation the period of each term is the same.*

Of course we must not conclude that the motion is in general a periodic one, *i.e.* to say that after a certain period T, ω will make exactly the same variations as in the time from $t = 0$ to $t = T$. Aside from the existence of the dampening factor $e^{-c^2 t}$, that could only occur if the periods of all of the terms, of which ω is the sum, were commensurable. This, of course, is only an exceptional case. But roughly speaking the motion will be periodic, not recurring exactly, but at least approximately after the lapse of a certain time, or at any rate oscillating to and fro.

The nature of these oscillations depends upon the mass and figure of *Jupiter* and his atmosphere, as well as upon the nature of the latter and upon the initial conditions at a given time $t = 0$. If $\omega = \omega_0 = f(r)$ for $t = 0$ is known, ω is determined as function of r and t for all succeeding time.

Under the conditions here supposed and also under more general circumstances which it is needless to recapitulate I have shown in my thesis that ω is a function of r and t only and not of z. We have seen however that the periods of the terms of which ω is the sum can depend only on z. They must therefore be constants, *i.e.* the quantities denoted in (11) by c and λ are constants, so that *the*

variations in ω must have the same law for all points of the atmosphere. Only the coefficients A and B which depend on r will change from spot to spot. This result is capable of being tested by observation.

The results obtained are, of course, also applicable to terrestrial meteorology, although they may there be of less importance, owing to the fact that the terrestrial atmosphere is comparatively shallow. Other deviations from the uniform circular motion, which can be treated by methods in my possession, are probably more important there.

Washington, D.C., 1898 *July* 2.

OBSERVATIONS OF COMETS.

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 12-INCH EQUATORIAL,

By PROF. E. FRISBY, U.S.N.

[Communicated by Prof. WM. HARKNESS, U.S.N., Astronomical Director.]

1898 Washington M.T.	∗	No. Comp.	☄ − ∗ Δα	☄ − ∗ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			Comet (b) Perrine.					
Mar. 25 16h 56m 59.6s	1	10 , 2	+2m 27.35s	− 2′ 6.7″	21h 40m 42.01s	+22° 49′ 30.2″	n9.6621	0.6075
Apr. 1 15 58 47.4	2	20 , 4	+1 6.48	+ 5 3.1	22 9 7.15	+29 47 16.6	n9.7194	0.6330
3 16 22 11.0	3	20 , 4	+2 8.01	− 0 46.8	22 17 50.60	+31 42 53.9	n9.7200	0.5837
6 14 46 4.3	4	20 , 4	−1 13.67	+ 1 32.0	22 31 22.35	+34 25 25.3	n9.7416	0.7088
8 15 24 25.4	5	10 , 2	+3 57.52	− 2 40.3	22 40 15.00	+36 12 31.2	n9.7556	0.6584
12 14 45 36.8	6	18 , 4	−1 11.80	+ 9 51.9	22 56 49.53	+39 30 25.9	n9.7866	0.7094
20 14 27 17.3	7	10 , 2	+5 15.91	+ 3 53.2	23 39 37.52	+45 13 9.6	n9.7944	0.7286
14 27 17.3	8	10 , 2	+2 53.44	− 3 15.2	23 39 37.52	+45 13 11.9	n9.7944	0.7286
29 13 24 44.0	9	14 , 3	+0 10.86	+ 7 13.7	0 27 38.70	+50 3 3.7	n9.7543	0.8202
May 17 12 42 17.6	10	20 , 4	−4 4.65	− 3 23.3	2 3 53.97	+55 12 55.1	n9.6706	0.8899
18 12 39 22.1	10	17 , 4	+0 59.53	+ 5 4.1	2 8 58.25	+55 21 22.4	n9.6611	0.8989
			Comet (c) Coddington.					
June 20 10 33 26.3	11	25 , 5	+0 21.30	+ 5 43.5	15 53 54.43	−30 47 7.3	9.2336	0.9154
22 11 3 27.3	12	20 , 4	−1 4.58	+ 5 16.0	15 46 10.83	−31 58 22.8	9.2791	0.9088
24 9 44 43.9	13	18 , 4	+2 40.12	+ 0 15.7	15 41 23.72	−33 9 27.7	8.5946	0.9237
			Comet (e) Perrine.					
June 20 13 17 25.2	14	5 , 1	−2 7.22	− 1 59.6	4 4 33.93	+57 10 1.5	n9.7972	0.8586
			Comet (f) Giacobini.					
June 22 12 8 2.1	15	20 , 4	−0 24.02	+11 56.7	19 46 16.54	−22 16 28.8	n9.2909	0.8760

Mean Places for 1898.0 of Comparison-Stars.

∗	α	Red. to app. place	δ	Red. to app. place	Authority
1	21h 38m 14.29s	+0.37s	+22° 51′ 42.9″	− 6.0″	Weisse's Bessel 21h898
2	22 8 0.37	+0.30	+29 42 18.7	− 5.2	Weisse's Bessel 22h145
3	22 15 42.32	+0.27	+31 43 45.8	− 5.1	Leiden A.G. Zones 7 , 27 and 9 , 27
4	22 32 35.82	+0.20	+34 23 57.8	− 4.5	Leiden A.G. Zones 234 , 4 and 339 , 4
5	22 36 17.28	+0.20	+36 15 16.0	− 4.5	Lund A.G. Zones 357 , 35 and 358 , 19
6	22 58 1.15	+0.18	+39 20 37.4	− 3.4	Lund A.G. Zones 44 , 27 and 47 , 27
7	23 34 21.51	+0.10	+45 9 18.6	− 2.2	Bonn A.G. Cat. 18013
8	23 36 43.99	+0.09	+45 16 29.1	− 2.0	Bonn A.G. Cat. 18054
9	0 27 27.69	+0.15	+49 55 49.8	+ 0.2	Bonn A.G. Cat. 410
10	2 7 58.26	{ +0.36 { +0.46	+55 16 15.4	+ 3.0 } + 2.9 }	Hels. and Gotha 4995 Hels. and Gotha 4995
11	15 53 28.78	+4.35	−30 52 31.8	−16.0	Yarnall (F) 6711
12	15 47 41.11	+4.30	−32 3 22.0	−16.8	Gould 15 3237
13	15 38 39.33	+4.27	−33 9 25.4	−18.0	Gould 15 2591
14	4 6 39.61	+1.54	+57 11 59.6	+ 1.5	Hels. and Gotha 3434
15	19 46 36.30	+1.26	−22 28 31.0	+ 8.5	München 22054

ELEMENTS AND EPHEMERIS OF COMET g 1898 (*GIACOBINI*).

By WILLIAM J. HUSSEY.

From the Nice observation of June 19 and Mt. Hamilton observations of June 23 and 27, I have computed the following elements of this comet:

$$T = 1898 \text{ July } 25.81828 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 22^\circ\ 11'\ 26''.5 \\ \Omega &= 278\ \ 17\ \ 30.3 \\ i &= 166\ \ 50\ \ 58.1 \end{aligned}\right\} 1898.0$$

$$\log q = 0.175956$$

$$\text{O}-\text{C}: \quad \Delta\lambda \cos\beta = -1''.8 \quad , \quad \Delta\beta = +2''.1.$$

Mt. Hamilton, Cal., 1898 *July* 2.

Constants for the Equator of 1898.0.

$$x = r[9.988706] \sin(v+191^\circ\ 10'\ 44''.0)$$
$$y = r[9.970315] \sin(v+279\ \ 6\ \ 18.7)$$
$$z = r[9.625766] \sin(v+313\ \ 53\ \ 58.2)$$

Ephemeris for Greenwich Midnight.

Gr. M.T.	True α	True δ	log Δ	Br.
	h m s	° ′		
1898 July 4.5	16 46 33	−18 5.8	9.754	1.36
8.5	15 53 18	−11 54.8	9.803	
12.5	15 17 16	−12 3.3	9.861	0.85
16.5	14 51 2	− 9 14.5	9.919	
20.5	14 31 52	− 7 56.9	9.975	0.52
21.5	14 17 39	− 6 33.9	0.026	
28.5	14 6 57	− 5 29.7	0.073	0.33

ELEMENTS AND EPHEMERIS OF COMET e 1898 (*PERRINE*).

By C. D. PERRINE.

From my observations of this comet on June 17, 24 and July 1, I have obtained the following system of elements:

$$T = 1898 \text{ August } 16.23871 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 205^\circ\ 12'\ 18''.2 \\ \Omega &= 259\ \ 10\ \ 16.4 \\ i &= 70\ \ \ 0\ \ 10.8 \end{aligned}\right\} 1898.0$$

$$\log q = 9.800186$$

$$\text{O}-\text{C}: \quad \Delta\lambda \cos\beta = -2''.5 \quad , \quad \Delta\beta = +4''.0$$

Constants for the Equator of 1898.0

$$x = r[9.585297] \sin(175^\circ\ 59'\ \ 4''.8+v)$$
$$y = r[9.999854] \sin(\ 89\ \ 32\ \ 31.0+v)$$
$$z = r[9.965361] \sin(180\ \ \ 9\ \ 29.9+v)$$

Ephemeris for Greenwich Mean Midnight.

1898	True α	True δ	log. Δ	Br.
	h m s	° ′		
July 16.5	6 17 48	+43 2.5	0.2184	3.39
18.5	26 15	41 24.3		
20.5	34 30	39 41.4	0.2094	4.01
22.5	42 33	37 53.8		
24.5	50 25	36 1.1	0.2007	4.74
26.5	6 58 9	34 3.7		
28.5	7 5 45	32 1.6	0.1921	5.56
30.5	13 15	29 54.6		
Aug. 1.5	20 42	27 42.7	0.1839	6.47
3.5	28 8	25 26.1		
5.5	35 33	23 5.0	0.1762	7.39
7.5	43 0	20 39.8		
9.5	50 31	18 10.8	0.1692	8.22
11.5	7 58 7	+15 38.0		
Aug. 13.5	8 5 50	+13 2.1	0.1631	8.83
15.5	13 43	10 23.4		
17.5	21 45	7 43.0	0.1584	9.08
19.5	29 58	5 1.7		
21.5	38 21	+ 2 20.2	0.1554	8.94
23.5	46 56	− 0 21.0		
25.5	8 55 44	3 1.0	0.1546	8.42
27.5	9 4 41	5 38.8		
29.5	13 56	8 13.9	0.1564	7.63
31.5	23 18	10 45.4		
Sept. 2.5	32 51	13 12.8	0.1607	6.71
4.5	42 34	15 35.2		
6.5	9 52 26	17 52.4	0.1678	5.76
8.5	10 2 26	20 3.9		
10.5	12 32	22 9.4	0.1773	4.87
12.5	22 43	24 8.4		
14.5	32 58	26 1.0	0.1890	4.07
16.5	43 16	27 47.2		
18.5	10 53 36	29 27.0	0.2024	3.38
20.5	11 3 55	31 0.3		
22.5	14 13	32 27.4	0.2171	2.80
24.5	24 29	33 48.3		
26.5	34 41	35 3.3	0.2327	2.32
28.5	44 49	36 12.6		
30.5	11 54 50	37 16.5	0.2489	1.93
Oct. 2.5	12 4 46	38 15.3		
4.5	12 14 32	−39 9.3	0.2654	1.60

The unit of brightness is that at discovery.

The comet is growing brighter and a faint nucleus has been seen.

Mount Hamilton, California, 1898 *July* 11.

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THE ORBIT OF THE SATELLITE OF *NEPTUNE*,

BY A. HALL.

The elaborate series of measurements of the satellite of *Neptune* made by Professor BARNARD with the 40-inch glass of the Yerkes Observatory (*A.J.*, No. 436), has led me to compare my elements of this satellite, computed in 1883, with these observations, and to determine the corrections to the elements. The motion of the planet in fifteen years has made the apparent orbit of the satellite more favorable for the determination of some of the elements. The orbit for 1883.0 was brought forward to 1898.0 by means of the daily motion of the satellite, $n = 61°.25742$, and the motion of the orbit-plane pointed out by MARTH. In this way the elements were found to be

$$\begin{aligned} \text{Epoch} &= 1898.0 \text{ Greenwich M.T.} \\ u &= 308°.60 \\ J &= 117\ .80 \\ N &= 186\ .50 \\ n &= 61\ .25742 \\ a &= 16''.30 \end{aligned}$$

The value of a is for the distance of the planet 30.0705.

The times of the observations were reduced to Greenwich, and corrected for aberration. The results of comparing with the above elements are given in the following table, the differences being in the sense calculated *minus* the observed position.

		sdp		*ds*
	h m	″	h m	″
1897 Sept. 14	16 38.2	−0.09	16 51.7	−0.11
20	17 36.2	+0.07	17 43.4	−0.02
22	17 8.8	+0.15	17 16.1	+0.32
24	18 26.9	+0.03	18 32.4	+0.41
26	16 54.2	+0.15	16 59.6	+0.02
Oct. 3	16 35.3	+0.07	16 44.8	−0.03
6	17 47.7	−0.09	17 55.6	+0.34
8	15 59.4	+0.12	16 6.7	−0.30
12	15 30.2	+0.26	15 38.7	+0.27
14	15 30.4	+0.15	15 37.7	+0.50
25	15 6.6	+0.36	15 13.3	+0.27
26	14 1.1	−0.09	14 6.7	+0.19
Nov. 2	15 41.6	+0.40	15 49.3	+0.04
9	17 37.5	−0.04	17 46.0	+0.21
22	13 7.8	−0.04	13 13.7	+0.61
23	13 26.4	−0.32	13 36.1	+0.44
Dec. 6	17 9.9	+0.14	17 19.8	−0.26
7	16 27.7	−0.30	16 38.2	+0.15
20	16 45.3	−0.10	16 57.3	+0.29
21	14 27.5	−0.24	14 38.2	+0.38
25	12 3.8	+0.05	12 15.1	−0.01
26	11 8.0	+0.15	11 15.8	−0.01
27	11 27.0	+0.09	11 33.8	+0.16
29	11 2.3	−0.15	11 10.6	+0.26
1898 Jan. 1	9 53.0	+0.14	10 0.0	+0.06
2	12 13.8	−0.16	12 19.0	+0.36
3	15 2.4	+0.76	15 12.0	−0.02
1898 Jan. 16	12 57.3	−0.07	13 8.5	−0.11
17	11 43.8	+0.35	11 53.2	−0.15
18	9 50.9	+0.33	10 5.3	+0.19
23	9 48.6	+0.58	9 57.7	0.00
27	13 2.4	+0.34	13 9.6	+0.16
Feb. 23	10 26.3	−0.12	10 32.2	0.00
26	9 53.8	+0.32	10 2.4	+0.04
Mar. 2	10 9.8	+0.01	10 16.3	+0.18
5	8 52.1	+0.01	8 58.2	+0.08
6	8 15.9	+0.17	8 51.3	+0.05
7	8 39.3	−0.02	8 45.4	+0.25
13	8 41.4	+0.09	8 57.4	+0.10
13	9 25.7	−0.21	9 29.8	−0.12
14	8 59.5	−0.15	9 14.8	+0.30
15	8 56.0	−0.17	9 3.3	+0.32
19	8 56.7	−0.38	9 4.9	+0.13
23	9 6.8	+0.16	9 17.1	−0.11
23	9 35.6	+0.36	9 43.0	−0.23
29	9 20.8	+0.10	9 26.8	−0.02
Apr. 1	9 49.4	+0.36	9 57.8	+0.34
2	9 39.0	+0.43	9 47.6	−0.41
3	9 29.4	+0.32	9 35.9	−0.29
5	9 34.3	−0.04	9 39.6	−0.08
11	9 43.2	+0.23	9 48.6	+0.34
20	9 58.3	+0.36	10 4.2	+0.03
23	9 31.8	−0.04	9 38.5	+0.33

An inspection of the above residuals shows that the assumed orbit is nearly right. The coefficients of the equations of condition were computed by the formulas of MARTH, which have some real advantages. These formulas are

$$s\,dp = +r\sin\tau\,.\,du + [r\sin\tau\cos J + r\cos\tau\cos u\sin J]\,.\,dN$$
$$-r\cos\tau\sin u\,.\,dJ - r\sin\tau\cos u\,.\,2e\sin Q + r\sin\tau\sin u\,.\,2e\cos Q$$
$$ds = +r\cos\sigma\cos\tau\,.\,du + r\cos\sigma\sin p\cos\delta\,.\,dN + r\cos\sigma\sin\tau\sin u\,.\,dJ$$
$$-\left[r\cos\sigma\cos\tau\cos u + \frac{s}{2}\sin u\right].\,2e\sin Q + \left[r\cos\sigma\cos\tau\sin u - \frac{s}{2}\cos u\right].\,2e\cos Q + s\,.\,\frac{da}{a}$$

σ and τ are the auxiliary angles of Marth, e is the eccentricity of the orbit, and Q is the angle of the line of apsides. The observations were made during an unfavorable season of the year, and the notes indicate difficulties in observing, but usually more time and care are given to such cases, and I have assigned the weight unity to each of the observations. Reducing the 106 equations of condition by the method of least squares the normal equations are as follows: where

$$\eta = 2e\sin Q\ :\ \ \xi = 2e\cos Q,$$

$$+10016.0\,.\,du - 1837.5\,.\,dN - 1568.2\,.\,dJ - 359.4\,.\,\eta - 253.0\,.\,\xi - 526.8\,.\,\frac{da}{a} - 56.81 = 0$$
$$+2848.2\,.\,dN + 348.6\,.\,dJ + 14.5\,.\,\eta + 100.5\,.\,\xi - 448.0\,.\,\frac{da}{a} - 23.42 = 0$$
$$+4850.9\,.\,dJ - 150.6\,.\,\eta - 41.8\,.\,\xi - 3464.6\,.\,\frac{da}{a} - 36.38 = 0$$
$$+4062.7\,.\,\eta + 1289.2\,.\,\xi - 121.2\,.\,\frac{da}{a} - 14.98 = 0$$
$$+8514.7\,.\,\xi - 325.3\,.\,\frac{da}{a} + 47.12 = 0$$
$$+10092.3\,.\,\frac{da}{a} + 77.81 = 0$$

The solution of these equations gives

$\log du$	$= 7.94205$	and hence du	$= +\ 0^\circ.50 \pm 0^\circ.093$
" dN	$= 8.09937$	dN	$= +\ 0.72 \pm 0.168$
" dJ	$= 7.79393$	dJ	$= +\ 0.36 \pm 0.145$
" η	$= 7.81885$	Q	$= 134.91 \pm 12.44$
" ξ	$= 7.81742n$	e	$= 0.004652 \pm 0.001011$
" $\frac{da}{a}$	$= 7.67126n$	a	$= 16''.224 \pm 0''.0280$

The sum of the squares of the residuals is reduced from

$$[nn] = 6.4675 \quad \text{to} \quad [nn.6] = 4.6766$$

and the probable error of a single observation is $\pm 0''.146$. The observations are very good. It has been necessary to reduce the observed distances to the times of the angles, and although this is easily done by means of the coefficients in the equations of condition, this reduction can generally be avoided by a simple and symmetrical arrangement of the observations. The eccentricity is very small, as in all the previous determinations, and for an ephemeris it may be put equal to zero. The position of the line of apsides is of course uncertain. For the mass of the planet from Professor Barnard's measurements we have from the value of a, and the mean motion of the planet and satellite,

$$\text{Mass of } Neptune = \frac{1}{19597 \pm 101}$$

I am indebted to Professor S. J. Brown of the Naval Observatory for the communication of data to which I have not access at this place. By comparison with the positions of the orbit plane found by Bond, Lassell, and O. Struve, and assuming the motion to be uniform, the annual variations of N and J are as follows:

$$\Delta N = +0^\circ.164\ : \quad \Delta J = -0^\circ.159$$

The values found by H. Struve are $+0^\circ.148$, and $-0^\circ.165$. Hence the new orbit of the satellite is

Epoch	=	1898.0 Greenwich M.T.
u	=	$309^\circ.10$
J	=	$118.16 - 0^\circ.159\,.\,(t-1898)$
N	=	$187.22 + 0^\circ.164\,.\,(t-1898)$
Q	=	$134.91 \pm 12^\circ.44$
e	=	0.004652 ± 0.001011
a	=	$16''.224$

Marth first called attention to the interesting motion of the orbit plane of this satellite, which became evident after the publication of my orbit of 1883. Tisserand and Newcomb pointed out that this motion is probably caused by an equatorial bulging of the planet. The observations indicate that the motion is uniform with the time, and when they have been extended over many years the position of the equator of the planet will be determined by this motion. But the motion is slow, and at the present time assumptions have to be made on the physical constitution of the planet, and on the centrifugal force at its equator. so that only wide and uncertain limits can be found for the flattening of the planet, and the time of its axial rotation. But these circumstances make the orbit of this satellite an interesting one. Observations can be made in the coming year under good conditions, since the apparent orbit is opening. Each observer. however, should make a complete and careful series of measurements, as Professor Barnard has done, since sporadic observations are of little value.

Gunstock, Conn., 1898 *July* 13.

OBSERVATIONS OF COMETS AND ASTEROIDS.

MADE WITH THE 18-INCH EQUATORIAL OF THE FLOWER OBSERVATORY, UNIVERSITY OF PENNSYLVANIA,

BY HENRY B. EVANS.

1898 Greenwich M.T.		*	No. Comp.	☌ — * $\Delta\alpha$	$\Delta\delta$	☌'s apparent α	δ	log $p\Delta$ for α	for δ
				COMET *b* 1898 (PERRINE).					
	h m s			m s	′ ″	h m s	° ′ ″		
Mar. 31	21 36 21	11	8 , 12	−1 21.85	− 3 27.9	22 4 57.63	+28 50 7.1	*n*9.692	0.602
	21 36 21	12	8 , 12	−1 48.18	− 3 14.3	22 4 57.82	+28 50 8.2	. .	. .
Apr. 1	21 5 54	13	7 , 11	+1 6.31	+ 5 3.2	22 9 6.79	+29 47 17.2	*n*9.710	0.640
	21 5 54	14	6	+0 26.93	. . .	22 9 6.97	. . . .	. .	. .
2	20 19 2	15	4	+2 3.47	− 5 16.4	22 13 16.51	+30 43 2.2	*n*9.720	0.700
	20 19 2	16	4	−3 7.14	− 4 40.7	22 13 16.60	+30 43 4.3	. .	. .
3	20 39 6	17	7 , 8	−3 36.56	+10 50.9	22 17 40.96	+31 41 11.8	*n*9.724	0.668
5	20 45 37	19	7 , 8	+3 34.32	+ 3 49.9	22 26 34.67	+33 32 32.9	*n*9.732	0.649
6	20 41 48	20	8	−1 30.97	+ 2 54.8	. . . .	. . . .	*n*9.737	0.650
7	20 46 59	21	8	+1 46.64	− 2 1.2	22 35 40.71	+35 20 27.5	*n*9.741	0.637
8	21 15 47	22	8	−5 7.47	+ 4 3.6	22 40 23.98	+36 13 58.2	*n*9.739	0.579
11	21 17 40	23	8	+1 39.76	− 0 36.0	22 54 37.85	+38 45 8.9	*n*9.753	0.556
12	20 22 15	24	8	−1 40.83	− 0 53.2	22 59 17.46	+39 31 25.6	*n*9.765	0.662
13	20 11 43	25	4	+1 41.57	− 2 2.7	23 4 9.74	+40 18 11.1	*n*9.768	0.677
May 9	20 20 49	26	8	−1 31.51	− 1 6.3	1 22 29.13	+53 36 9.5	*n*9.867	0.654
	20 20 49	27	8	−2 19.04	− 0 46.9	1 22 29.17	+53 36 10.5	. .	. .
11	19 56 7	28	9	+0 18.39	+ 0 41.7	1 33 5.53	+54 5 37.9	*n*9.857	0.708
13	19 55 32	29	10	−0 18.54	− 5 56.9	1 43 40.01	+54 20 41.7	*n*9.857	0.712
	20 28 6	30	8	+1 30.39	− 5 26.6	1 43 47.22	+54 20 58.4	*n*9.877	0.645
17	20 6 55	31	9	−3 34.99	− 2 28.2	2 4 23.64	+55 13 49.6	*n*9.870	0.695
	20 9 33	32	8	−3 37.55	− 5 11.6	2 4 24.20	+55 13 51.3	*n*9.872	0.689
31	19 44 6	33	10	−0 44.92	+ 1 6.0	3 10 12.80	+56 17 19.7	*n*9.854	0.750
June 22	19 27 21	34	8	−1 27.20	+ 0 54.6	4 30 11.34	+55 33 5.7	*n*9.846	0.768
23	19 36 45	34	8	+1 33.98	− 4 59.0	4 33 12.52	+55 27 12.1	*n*9.844	0.752
	19 36 45	39	8	−1 29.85	− 2 25.1	4 33 12.68	+55 27 12.0	. .	. .
24	19 26 8	41	5 , 8	+0 23.82	+ 2 22.9	4 36 8.46	+55 23 3.5	*n*9.834	0.768
	19 50 6	41	8	+0 26.57	+ 2 20.0	4 36 11.21	+55 23 0.6	*n*9.856	0.728
				COMET *c* 1898 (CODDINGTON).					
June 22	17 8 48	35	8	−1 13.46	+ 3 53.6	15 46 31.94	−31 59 45.9	9.496	0.879
23	15 46 17	37	8	−0 11.42	− 2 11.2	15 43 9.77	−32 32 9.8	9.208	0.910
				COMET *e* 1898 (PERRINE).					
June 22	18 55 45	36	8	+0 1.07	− 6 30.7	4 16 38.60	+56 31 41.6	*n*9.825	0.792
23	19 6 30	38	8	+0 28.90	− 3 21.7	4 22 36.15	+56 10 40.6	*n*9.831	0.780
24	19 8 4	40	8	−1 5.41	− 5 57.4	4 28 25.72	+55 48 34.6	*n*9.827	0.782

1898 Greenwich M.T.		*	No. Comp.	Planet — * $\Delta\alpha$	$\Delta\delta$	Planet's apparent α	δ	log $p\Delta$ for α	for δ
				(213) *Lilaea.*					
	h m s			m s	′ ″	h m s	° ′ ″		
Feb. 9	17 42 19	1	10 , 7	+2 26.68	+ 0 42.2	9 10 19.24	+18 53 54.0	9.038	0.516
10	16 44 46	3	14 , 10	+0 48.96	− 3 6.4	9 9 29.12	+18 58 53.8	*n*7.202	0.506
Mar. 1	17 47 46	9	8	−2 12.68	− 3 2.5	8 54 38.12	+20 28 22.8	9.481	0.545
	17 47 46	10	8	−3 20.10	+ 0 29.2	8 54 37.95	+20 28 23.4	. .	. .
				(207) *Hedda.*					
Feb. 27	15 30 2	6	6 , 8	+4 4.69	− 0 29.0	9 5 9.02	+22 48 2.4	*n*7.971	0.420
	15 30 2	7	7 , 8	+3 4.68	− 3 46.6	9 5 9.09	+22 48 3.0	. .	. .
Mar. 1	14 52 56	6	8 , 6	+2 32.01	+ 1 18.8	9 3 36.34	+22 49 50.2	*n*8.956	0.427
	14 52 56	7	8 , 6	+1 31.99	− 1 59.0	9 3 36.40	+22 49 50.6	. .	. .
				(321) *Florentina.*					
Mar. 1	16 5 14	8	9 , 12	−0 32.79	− 1 24.5	9 37 52.76	+18 7 12.3	8.141	0.521

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	9 7 49.62	+2.94	+18 53 21.2	− 9.4	Micrometer-comparison, *2
2	9 8 32.13	+2.93	+18 40 45.8	− 9.4	Auwers, Berlin A.G. Catal. 3732
3	9 8 37.22	+2.94	+19 2 9.6	− 9.4	Micrometer-comparison, *4 and *5
4	9 8 18.25	+2.94	+19 3 55.9	− 9.4	Auwers, Berlin A.G. Catal. 3735
5	9 8 13.28	+2.94	+19 8 57.4	− 9.4	" " " " 3733
6	9 1 1.29	+3.04	+22 48 39.5	− 8.1	Becker, " " " 3651
7	9 2 1.37	+3.04	+22 51 57.7	− 8.1	" " " " 3660
8	9 38 22.55	+3.00	+18 8 28.2	−11.4	Auwers, " " " 3912
9	8 56 47.82	+2.98	+20 31 33.5	− 8.2	Becker, " " " 3633
10	8 57 55.07	+2.98	+20 28 2.5	− 8.3	" " " " 3638
11	22 6 19.17	+0.31	+28 53 40.1	− 5.1	Graham, Camb. A.G. Catal. 13257
12	22 6 46.00	+0.30	+28 53 27.6	− 5.1	" " " " 13259
13	22 8 0.18	+0.30	+29 42 19.2	− 5.2	" " " " 13277
14	22 8 39.74	+0.30	+29 44 28.7	− 5.1	" " " " 13290
15	22 11 12.76	+0.28	+30 48 23.8	− 5.2	Leyden A.G. Zones, 2 obs.
16	22 16 23.47	+0.27	+30 47 49.8	− 4.8	" " " "
17	22 21 17.26	+0.26	+31 30 25.6	− 4.7	Micrometer-comparison with *18
18	22 23 5.87	+0.26	+31 19 6.5	− 4.5	⅓ {4 Glasgow (2) 1952 + Armagh 4932}
19	22 23 0.11	+0.24	+33 28 48.0	− 5.0	Leyden A.G. Zones, 3 obs.
20	22 32 33.	+0.21	+34 23.6	− 4.5	
21	22 33 53.87	+0.20	+35 22 33.2	− 4.5	Lund A.G. Zones, 6 obs.
22	22 45 31.27	+0.18	+36 9 58.5	− 3.9	" " " "
23	22 52 57.91	+0.18	+38 45 48.6	− 3.7	½ {Brussels 10281 + Yarnall 10387}
24	23 0 58.13	+0.16	+39 32 22.0	− 3.2	Lund A.G. Zones, 4 obs.
25	23 2 28.01	+0.16	+40 20 17.1	− 3.3	Deichmüller, Bonn A.G. Catal. 17456
26	1 24 0.38	+0.26	+53 37 13.8	+ 2.0	Rogers, Cambridge A.G. Catal. 673
27	1 24 47.95	+0.26	+53 36 55.3	+ 2.1	" " " " 677
28	1 32 46.83	+0.31	+54 4 53.9	+ 2.3	" " " " 738
29	1 43 58.20	+0.35	+54 26 36.0	+ 2.6	" " " " 838
30	1 42 16.48	+0.35	+54 26 22.5	+ 2.5	" " " " 826
31	2 7 58.20	+0.43	+55 16 14.8	+ 3.0	{½ Rogers, Cambridge A.G. Catal. 1037 + Krueger, Hels. and Gotha A.G. Catal. 1995}
32	2 8 1.32	+0.43	+55 18 59.9	+ 3.0	{½ Rogers, Cambridge A.G. Catal. 1038 + Krueger, Hels. and Gotha A.G. Catal. 1999}
33	3 10 56.85	+0.87	+56 16 10.4	+ 3.3	Krueger, Hels. and Gotha A.G. Catal. 2901
34	4 31 36.91	+1.63	+55 32 9.5	+ 1.6	" " " " " 3665
35	15 47 41.10	+4.30	−32 3 22.7	−16.8	Gould, Zone Catal. 15h3237
36	4 16 35.90	+1.63	+56 38 10.7	+ 1.6	Krueger, Hels. and Gotha A.G. Catal. 3527
37	15 13 16.91	+4.28	−32 29 41.2	−17.4	Gould, Zone Catal. 15h2944
38	4 22 5.59	+1.66	+56 14 0.8	+ 1.5	Krueger, Hels. and Gotha A.G. Catal. 3574
39	4 34 40.88	+1.65	+55 29 35.5	+ 1.6	" " " " " 3696
40	4 29 29.45	+1.68	+55 54 30.5	+ 1.5	" " " " " 3649
41	4 35 42.97	+1.67	+55 20 39.1	+ 1.5	" " " " " 3708

Flower Observatory, 1898 *July* 9.

MAXIMA AND MINIMA OF LONG-PERIOD VARIABLES.

By J. A. PARKHURST.

The following observations were made with the 6.2-inch Brashear reflector, except that the last two (June) comparisons for *RT* and *RZ Cygni*, and *V Delphini* were made with the 12-inch refractor of the Yerkes Observatory, but in no case would the change of instruments affect the date or magnitude of the maximum or minimum.

678. *U Persei.*

Since the maximum reported in *A.J.* 426 I have 16 observations between 1897 Dec. 29 and 1898 May 21. The star followed the usual curve, falling from 8M.7 to a minimum, 11M.8, March 26. From five minima which I have observed since 1893 the interval $M-m$ averages 417 days.

2404. *X Geminorum.*

I have 21 observations of this star between 1898 Jan. 4 and May 25. It fell steadily from 9M.1 to a well marked minimum, 11M.75, March 7, then rose to 9M.0 at the last observation, after which it was lost in the evening twilight. The rise during May was about as rapid as in April.

2815. *U Geminorum.*

The following observations of the May maximum were secured.

Gr. Time.			Gr. Time.	
1898 April 26.60	<13^M		1898 May 11.59	11^M.0
May 7.58	9.85		16.62	<13

Taken in connection with the observations of Mr. Zaccheus Daniel, published in *Popular Astronomy* for June, 1898, page 248, it appears that the maximum occurred about May 6.

4471. *T Canum Venaticorum.*

A series of sixteen observations, beginning 1897 Oct. 25 and ending 1898 May 21, show a maximum at 8^M.6, 1898 Feb. 20. The curve was rather flat at maximum and the time say 10 or 15 days in error. A comparison with last season's observations (*A.J.* 426) suggest a period of nine or ten months. The magnitudes were 11^M.0 and 10^M.5, at the first and last dates respectively.

5601. *S Ursae minoris.*

This star fell from 8^M.7, 1897 Dec. 29, to a minimum, 11^M.3, 1898 April 14, then rose to 9^M.3 at the last observation, June 17.

5798. *RU Herculis.*

After the minimum recorded in *A.J.* 426 this star rose rapidly to a well defined maximum, 8^M.5, 1898 March 13, then fell more slowly to 9^M.8, May 16. I have 11 observations between 1898 Jan. 18 and May 16. At maximum it was about equal to DM. +25°3036 and 3042, and fainter than +25°3031.

6100. *RV Herculis.*

This star has been followed closely since the minimum recorded in *A.J.* 434, and a maximum observed at 9^M.75, 1898 March 12 (possibly 10 days earlier). The last observation with the 6.2-inch was May 7, at 12^M.5, at which time the fall was rapid. The interval between the descending branches of the light curves at the last two maxima is about 213 days.

7085. *RT Cygni.*

A series of 17 comparisons between 1897 Dec. 29 and 1898 June 27 yields a maximum at 7^M.15, Feb. 16 (time uncertain by perhaps 10 days), and a well defined minimum, at 11^M.7, May 23. At the last observation the star had risen to 10^M.0.

7458. *U Delphini.*

After the maximum of 1896 November (*A.J.* Nos. 393, 394 and 397), I followed it till 1897 Jan. 28, finding it 11^M.3 at the last observation. It was looked for without success 1897 May, July, Aug. and Oct., and 1898 Feb. and March, and was glimpsed uncertainly at 12^M.2 Mar. 23. Four comparisons were then secured up to June 21, the resulting curve agreeing with the ephemeris maximum, 1898 May 12. The observations were too few to determine the magnitude at maximum.

7492. *RZ Cygni.*

A fairly defined maximum, at 10^M.5, is indicated for 1898 March 7, by 15 observations between 1897 Oct. 19 and 1898 June 25. The rise was a little faster than the decline, and the magnitudes at first and last dates were 12^M.7 and 11^M.8, respectively.

7792. *SS Cygni.*

The "long" maximum recorded in *A.J.* 434 was followed by a 41-day period of normal light. The star then began to rise 1898 March 20, a maximum at 8^M.5 was passed March 22.6, and normal light was reached April 2, giving a typical "short" maximum. This was followed by a 45-day period of normal light, ending May 17 with a rise to a maximum, 8^M.5, which was passed May 22.2. Normal light was reached June 6, giving a typical "long" maximum, lasting 20 days. These two maxima were covered by 16 observations.

Yerkes Observatory, 1898 *July* 8.

PRESENT ROTATION-PERIOD OF THE FIRST SATELLITE OF *JUPITER* AND ITS CHANGE IN FORM AND PERIOD SINCE 1892.

By A. E. DOUGLASS.

Observations of this satellite, made in the last two weeks, entirely confirm the period of rotation obtained by the writer a year ago, $12^h\ 25^m.8$, and recently communicated to the *Astronomische Nachrichten*. The period is obtained from the changes in form of the satellite, such as were first discovered by Professor W. H. Pickering, at Arequipa, in 1892. The method now used in measuring the oblateness is his, and consists in a constant comparison of the telescopic image with a "scale of ellipticities" fastened to the telescope-tube at a suitable distance from the eye. Care is taken that the conditions of viewing the scale simulate as closely as possible the conditions of observation at the telescope.

The scale is a piece of black cardboard, with a series of white paper ellipses pasted upon it. Each ellipse has a polar diameter of 10 mm.; their equatorial diameters increase by intervals of 0.4 mm. in succession from 9.6 mm. to 15.2 mm. In assigning a numerical quantity to any given form, the polar diameter is considered constantly 100, and it is only necessary to record the equatorial diam-

eter on that basis. Thus, form 100 is a perfect circle; form 120 has the equatorial diameter 20 per cent. greater than the polar.

In 1892 and 1893, Professor PICKERING did not use this scale, but at that time the phase of minimum ellipticity was almost a perfect circle, and as the circular form is something very definite to observe, he obtained very precise results. His period was $13^h\,3^m\,9^s$ or 25^s, and his range of ellipticity was from 100 to 110. His observations obtained with the scale in 1894, not yet rigorously reduced, proved the period to be approximately the same at that time, and the range of ellipticities to extend, roughly, from 108 to 120.

Observations by the writer, at Mexico, in the spring of 1897, though not made specially for this purpose, disclosed, on reduction, a period of $12^h\,25^m.8$, and a range of ellipticities from 115 to 125. A slight feeling that there was a chance for error in this result was felt until the present observations proved the present period to be closely $12^h\,25^m$, and the range of ellipticity to be from 112 to 121. These observations have been made for the purpose of determining this period; the minima have been extremely well marked, and the time of each depends upon fifteen to twenty comparisons distributed within the sixty to eighty minutes of rapid change. Therefore, it apparently becomes known to within a minute or two, but the very latest observations show that the period may be even shorter, a fact hard to explain, unless it is undergoing some further change, or is subject to a regular fluctuation.

The first minimum obtained was 1898 April $27^d\,17^h\,6^m.5$ G.M.T.; the second was May $5^d\,17^h\,35^m.0$; fifteen and a half rotations between these dates give a period of $12^h\,25^m.1$. The third minimum was on May $6^d\,18^h\,26^m.5$, giving from the day before a period of $12^h\,25^m.8$, but the fourth one observed was on May $10^d\,15^h\,9^m.5$, giving from the preceding a period of $12^h\,21^m.7$. This either indicates a change in the period, or some error of observation. But, even if it is the latter, a close agreement with this satellite's period in 1897 remains.

This, then, is the most rapid change in rotation-period of a heavenly body yet discovered. The only other known change has occurred in the equatorial zones of the planet *Jupiter*, whose period now seems to be a fraction of a minute longer than in 1879.

The evidence of change in form of this satellite is not so "orthodox" in character, yet there can be no question about the circular form occurring in 1892–3, and there is no question now but that, during its minimum phase, it is never seen to become anything less than conspicuously elliptical.

There is some evidence that it has diminished markedly in mean diameter since 1892–3, which will be discussed when new evidence is obtained to confirm or deny it. If such diminution has occurred it will help vastly in explaining by known mechanical laws the other changes already observed.

Lowell Observatory, Flagstaff, Arizona, 1898 *May* 12.

NOTES ON VARIABLE STARS, — No. 25,

BY HENRY M. PARKHURST.

RESULTS OF OBSERVATIONS.

No.	Star	Phase	Observed Date Julian	Calendar 1897–98	E	Corr.	W	Mag.	Factors		d	Remarks
2404	*X Geminorum*	Min.	4388	Apr. 8	–	–	2P	–	–	–	–	Magnitudes provisional
2478	*R Lyncis*	Min.	4320:	Jan. 30:	23	–59:	1	–	–	–	–	Invisible more than 3 months
2539	*R Canis min.*	Max.	4274	Dec. 15	42	+ 2	5P	7.8	–	–	–	Very long intervals
2625	*V Geminorum*	Max.	4375	Mar. 26	24	– 3	9	8.93	0.85	0.60	24	
2684	*S Canis min.*	Min.	4369	Mar. 20	39	+10	8	11.92	1.64	2.30	57	
2689	*Z Puppis*	Max.	4001	Mar. 17	–	–	3	8.21	0.50	0.50	17	1897. See *A.J.* 428
"	"	Min.	4344	Feb. 23	–	–	9	10.97	0.68	1.40	30	
"	"	Min.	4339	Feb. 18	–	–	6P	11.1	–	–	–	
2690	*X Puppis*	Max.	4344	Feb. 23	–	–	3	8.3	–	–	–	An uncertain maximum
2946	*R Cancri*	Max.	4263	Dec. 4	46	– 4	6P	6.7	–	–	–	Very long intervals
2976	*V Cancri*	Max.	4361	Mar. 12	36	– 2	9	7.86	4.0	2.0	28	Curve flat for 40 days
3060	*U Cancri*	Max.	4418	May 8	54	–14	9	8.92	0.58	0.81	15	
3170	*S Hydrae*	Min.	4374	Mar. 25	59	–19:	1	–	–	–	–	
3184	*T Hydrae*	Min.	4323:	Feb. 2	51	–	E	–	–	–	–	Assumed midway
3264	*W Cancri*	Max.	4381	Apr. 1	7	+20	6	9.8	–	–	–	Perhaps earlier
3493	*R Leonis*	Min.	4374	Mar. 25	165	– 1	8P	9.86	2.0	3.0	45	
3518	*Y Hydrae*	–	–	–	–	–	–	–	–	–	–	*A.J.* 392. Diminishing
3567	*V Leonis*	Max.	4277	Dec. 18	21	– 8	3	–	–	–	–	Approx. from factors [Catal.
3890	*W Leonis*	Max.	4299	Jan. 8	24	–	E	–	–	–	–	Much earlier than my ele. Second
3994	*S Leonis*	Max.	4397	Apr. 17	72	–51	6	10.5	–	–	–	Correction increasing
"	"	Max.	4393	Apr. 13	72	–55	4P	–	–	–	–	Interpolation with my factors

Individual Observations.

Including Observations by Arthur C Perry.

2404 X Geminorum.

Julian	Calendar		Mag.
	1898		
4293.5	Jan.	3	9.8
4335.5	Feb.	14	10.8
4363.6	Mar.	14	11.1P
4374.5		25	10.3
4374.6		25	11.4P
—	Apr.	–	11.7]
4388.6		8	12.0P
4400.6		20	11.1P
4419.5	May	9	10.0:P
4419.6		9	9.8
4420.6		10	9.63
4421.6		11	10.18

2478 R Lyncis.

(Continued from 377.)

Julian	Calendar		Mag.
	1897		
3930.6	Jan.	5	12.6]
4221.7	Oct.	23	11.0
4256.6	Nov.	27	11.8
4285.5	Dec.	27	12.6]
	1898		
4306.5	Jan.	16	13]
4374.5	Mar.	25	12.1]
4421.6	May	11	10.9

2539 R Canis min.

(Cont.from 403. Comp.Stars 403)

Julian	Calendar		Mag.
	1897		
4246.7	Nov.	17	8.2P
4253.7		24	8.0P
4258.7		29	7.8P
4278.6	Dec.	19	7.9P
	1898		
4306.6	Jan.	16	8.1P
4347.6	Feb.	26	8.7P
4363.6	Mar.	14	9.2P
4374.6		25	9.4P

2625 V Geminorum.

(Continued from 350.)

Julian	Calendar		Mag.
	1898		
4334.5	Feb.	13	10.1
4345.5		24	10.20$_2$
4347.5		26	9.91$_2$
4355.5	Mar.	6	9.25$_2$
4358.6		9	8.8P
4363.5		14	9.39$_2$
4363.6		14	8.4P
4368.5		19	8.91$_2$
4374.5		25	9.17$_2$

2625 V Gemin.—Cont.

Julian	Calendar		Mag.
	1898		
4374.6	Mar.	25	9.2P
4380.5		31	8.42$_2$
4386.5	Apr.	6	9.80$_2$
4388.6		8	9.6:P
4393.5		13	9.84$_2$
4400.6		20	9.8P
4419.6	May	9	9.6P
4427.6		17	8.9P

2684 S Canis min.

(Continued from 403.)

Julian	Calendar		Mag.
	1898		
4333.5	Feb.	12	11.40$_2$
4345.5		24	11.64$_2$
4363.5	Mar.	14	11.80$_2$
4374.6		25	12.02$_2$
4393.6	Apr.	13	11.41$_2$
4400.5		20	11.81$_2$
4419.6	May	9	11.4
4421.6		11	11.52$_2$

2689 Z Puppis.

Julian	Calendar		Mag.
	1897		
3988.6	Mar.	4	8.3P
3991.5		7	8.21$_2$
3991.6		7	8.3P
3994.5		10	8.45$_2$
3994.5		10	8.3P
3996.5		12	8.35$_2$
3998.6		14	8.13$_2$
4005.5		21	8.3P
4005.6		21	8.30$_2$
4010.6		26	8.4P
4012.5		28	8.77$_2$
4013.5		29	8.74$_2$
4014.6		30	8.6P
4016.6	Apr.	1	8.6P
4026.5		11	8.62$_2$
4026.5		11	8.6P
4032.5		17	8.40$_2$
4032.5		17	8.6P
4034.5		19	8.6P
	1898		
4330.6	Feb.	9	10.62$_3$
4331.6		10	10.09$_2$
4333.5		12	10.7P
4333.6		12	11.13$_2$
4334.6		13	11.1P
4335.5		14	10.78$_2$

2689 Z Puppis.—Cont.

Julian	Calendar		Mag.
	1898		
4345.5	Feb.	24	10.5
4345.6		24	10.9P
4347.5		26	11.10$_2$
4347.6		26	10.9P
4358.5	Mar.	9	10.7P
4358.6		9	10.51$_2$
4363.6		14	10.8P
4365.5		16	10.89$_2$
4374.6		25	10.7P
4380.5		31	10.76$_2$
4388.6	Apr.	8	10.7P
4393.5		13	10.98$_2$

2690 X Puppis.

(Cont.from 403. Comp.Stars 403)

Julian	Calendar		Mag.
	1898		
4331.6	Feb.	10	8.82$_2$
4347.6		26	8.3P
4358.5	Mar.	9	9.0P
4363.6		14	9.3P
4374.6		25	8.6P
4388.6	Apr.	8	9.3P

2946 R Cancri.

(Continued from 410.)

Julian	Calendar		Mag.
	1897		
4246.7	Nov.	17	7.2P
4253.7		24	7.1P
4258.7		29	6.7P
4278.6	Dec.	19	7.1P
	1898		
4306.6	Jan.	16	8.9P
4347.6	Feb.	26	10.4P
4363.6	Mar.	14	10.4P

2976 V Cancri.

(Continued from 410.)

Julian	Calendar		Mag.
	1898		
4334.5	Feb.	13	8.1
4335.5		14	7.97$_2$
4338.5		17	7.80$_2$
4345.5		24	7.86$_2$
4355.6	Mar.	6	7.92$_2$
4363.5		14	7.80$_2$
4366.5		17	7.95$_2$
4374.5		25	7.64$_2$
4381.5	Apr.	1	8.35$_2$
4387.5		7	7.82$_2$
4393.5		13	8.34$_2$

3060 U Cancri.

Continued from 410

Julian	Calendar		Mag.
	1898		
4334.5	Feb.	13 to	
4366.5	Mar.	17	12.5]
	4 dates		
4374.6	Mar.	25	12.5
4374.6		25	11.5:P
4388.6	Apr.	8	10.8P
4396.5		16	10.29$_2$
4401.6		21	9.64$_2$
4410.6		30	9.07$_2$
4419.6	May	9	8.82$_2$
4419.6		9	9.4P
4420.5		10	8.82$_2$
4421.5		11	9.33$_2$
4424.6		14	8.56$_2$
4427.6		17	9.18$_2$
4440.6		30	10.01$_2$

3170 S Hydrae.

(Continued from 410.)

Julian	Calendar		Mag.
	1898		
4331.6	Feb.	10	10.4]
4333.5		12	11.6:
4345.5		24	11.9:
4358.5	Mar.	9	11.6:
4374.6		25	12.1
4396.5	Apr.	16	11.83$_2$
4400.6		21	11.72$_2$

3184 T Hydrae.

(Continued from 410.)

Julian	Calendar		Mag.
	1898		
4331.6	Feb.	10	9.4]
4333.5		12	11.0]
4358.5	Mar.	9	12.6
4366.5		17	12.5
4396.5	Apr.	16	9.90$_2$

3264 W Cancri.

Cont.from 410. Comp.Stars 384

Julian	Calendar		Mag.
	1898		
4334.5	Feb.	13	12.1]
4366.5	Mar.	17	10.1
4367.5		18	10.02$_2$
4374.5		25	10.21$_2$
4380.5		31	9.58$_2$
4393.6	Apr.	13	10.48$_2$
4400.6		20	10.61$_2$

3493 R Leonis.

Continued from 410.

Julian	Calendar		Mag.
	1898		
4347.6	Feb.	26	9.7P
4358.6	Mar.	9	9.8P
4363.6		14	9.8P
4374.6		25	9.9P
4388.6	Apr.	8	9.8P
4400.6		20	9.8P
4419.6	May	9	9.6P
4427.6		17	8.9P

3518 Y Hydrae.

Julian	Calendar		Mag.
	1898		
4363.6	Mar.	14	6.9P
4388.6	Apr.	8	7.0P
4419.6	May	9	7.2P

3567 V Leonis.

(Continued from 410.)

Julian	Calendar		Mag.
	1897		
4258.7	Nov.	29	10.6P
	1898		
4334.5	Feb.	13	10.8
4335.5		14	10.85$_2$
4366.5	Mar.	17	12.9]

3890 W Leonis.

Continued from 410.

Julian	Calendar		Mag.
	1898		
4334.6	Feb.	13	12.0]
4363.6	Mar.	14	10.6]P
4458.6	June	17	12.1]

3994 S Leonis.

(Continued from 410.

Julian	Calendar		Mag.
	1898		
4334.6	Feb.	13	12.0]
4363.6	Mar.	14	11.6
4363.7		14	11.9P
4374.6		25	11.4
4387.5	Apr.	7	11.05$_2$
4392.6		12	10.63$_2$
4396.6		16	10.40$_2$
4400.6		20	10.55$_2$
4419.6	May	9	11.92$_2$
4419.6		9	11.3P
4427.6		17	11.3P
4446.6	June	5	11.7]P

Comparison-Stars. — 1893–1898

2684 S Canis minoris.

Star	DM.		Mag.	n
K	+8°1816		7.78	5
N	+8°1801		8.14	12
5R	+8°1807		8.43	8
1T	+8°1811		9.23	12
X	+8°1799		10.47	9
Z	+8°1805		10.41	8
e	4p	X	11.49	7
f	3f	X	11.61	10
j	2s1f	V	12.39	9
l	2s1f	f	12.73	4

2946 R Cancri.

Star	DM.		Mag.	n
1H	+11°1800		7.28	8
4I	+11°1796		7.64	6
K	+11°1806		7.84	10
3N	+12°1812		8.21	10
1T	+12°1804		8.99	2
1W	+12°1806		9.70	4
Y	+12°1809		10.38	2
Z	+12°1805		10.49	6
1Z	+12°1808		10.08	5
a	2n2p	1Z	10.11	2

2976 V Cancri.

Star	DM.		Mag.	n
K	+18°1923		8.06	7
L	+18°1927		7.83	11
M	+18°1926		8.09	11
Q	+18°1917		8.40	5
T	+17°1823		8.53	3
V	+18°1921		9.39	7
W	+17°1826		9.31	11
Z	+18°1922		10.66	2
1Z	+18°1918		10.52	4
a	6f	W	10.72	4

3567 V Leonis.

Star	DM.		Mag.	n
P	+22°2160		8.62	4
Q	+22°2153		8.64	13
R	+22°2163		9.07	4
U	+22°2151		9.80	13
1U	+22°2155		9.51	13
W	+22°2162		9.56	2
X	+22°2158		9.75	1
Z	+22°2150		10.59	7
1Z	+22°2152		10.53	6
f	5n	Q	11.36	2

THE DOUBLE STAR, *MAYER 867*,

$\alpha = 20^h\ 27^m$, $\delta = -16°\ 57'$,

BY R. T. A. INNES.

The only measure of this pair occurs in Professor SEE's list in *A.N.* 3496, col. 282. Professor SEE, however, assigns its discovery to LALANDE, and says that it was also observed double by ARGELANDER.

Two observations of this star will be found on page 177 of the *Histoire Céleste*, where it is called *Mayer 841*; one was made on the 13th, and the other on the 18th August, 1795. There is no note of duplicity to either observation, which, as reduced in the *B. A. Lalande*, show differences of $0^s.03$ and $1''.2$ in α and δ. LALANDE's telescope was probably under three inches aperture, and not achromatic, but I am not sure on these points. It would certainly not show such a star as a double. As for ARGELANDER's observations, they were made on the 9th and the 27th September, 1849, and undoubtedly refer to the same star, as there is no note of duplicity on either occasion.

In other words, this star as a double, is certainly Professor SEE's own discovery.

These remarks may save attempts to compute an orbit at present.

There are a considerable number of somewhat similar cases in Professor SEE's valuable list.

1898 *June* 24.

EPHEMERIS OF COMET *b* 1898 (PERRINE),

(Continued from No. 437, p. 40),

BY C. D. PERRINE.

Gr. Mean Midn't 1898	True α h m s	True δ ° ′	log Δ	Br.
Aug. 3.5	6 0 18	+52 24.4		
5.5	3 6	16.8	0.4573	0.07
7.5	5 47	9.4		
9.5	8 22	52 2.3		
11.5	10 49	51 55.4		
13.5	13 9	48.8	0.4597	0.06
15.5	15 22	42.6		
17.5	17 28	36.4		
19.5	19 27	30.7		
21.5	21 19	25.2	0.4602	0.06
23.5	23 4	20.0		
25.5	24 42	15.1		
27.5	26 12	10.5		
29.5	27 35	6.1	0.4591	0.05
31.5	6 28 51	+51 2.0		
Sept. 2.5	6 30 0	+50 58.2		
4.5	31 1	54.7		
6.5	31 55	51.4	0.4566	0.05
8.5	32 41	48.4		
10.5	33 19	45.7		
12.5	33 49	43.2		
14.5	34 11	41.0	0.4528	0.05
16.5	6 34 25	+50 39.0		

Brightness at discovery taken as unity.

The correction to this ephemeris on July 17 was

$$O-C: \quad -7^s \quad +1'.2$$

The comet is fading steadily, and is now of about the 12th magnitude.

Lick Observatory, University of California, 1898 *July* 18.

ELEMENTS OF COMET *c* 1898 (CODDINGTON),

BY E. F. CODDINGTON.

From Mt. Hamilton observations of June 11, 18, and 26, I have computed the following elements of this comet. The mean of three observations was used in forming the middle place, and the mean of two observations for the last place.

$$T = 1898 \text{ Sept. } 13.97347 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 233°\ 10'\ 31''.4 \\ \Omega &= 73\ 59\ 19.8 \\ i &= 69\ 56\ 47.3 \end{aligned}\right\} 1898.0$$

$$\log q = 0.231178$$

$$O-C: \quad \Delta\lambda \cos\beta = +4''.7 \quad , \quad \Delta\beta = +1''.8$$

CONSTANTS FOR THE EQUATOR, 1898.0

$$x = r[9.633249] \sin(v + 13°\ 15'\ 3''.3)$$

$$y = r[9.967249] \sin(v + 341\ 12\ 33.6)$$

$$z = r[9.990067] \sin(v + 256\ 13\ 1.2)$$

Mt. Hamilton, 1898 *July* 8.

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ON THE DEVELOPMENT OF THE PERTURBATIVE FUNCTION IN TERMS OF THE MEAN ANOMALIES,

By ALEXANDER S. CHESSIN.

A few years ago, while the author was computing for the use of Professor NEWCOMB's Astronomical Tables he noticed that there existed certain simple linear relations between the several terms of the perturbative function, the development then used being that of LEVERRIER. This discovery led to an investigation the result of which was the establishment by the author of the relations in question for the development of the perturbative function in terms of eccentric anomalies as given by Professor NEWCOMB in the third volume of his *Astronomical Papers.* These relations are given in No. 332 of this *Journal* (1894 December 21). The author had occasion to apply them, and found that they reduce the actual work of computing the terms of the perturbative function to about one-fourth or one-fifth of what it would be without their use. The importance of this economy of work is such that the author sought to establish similar relations for the development of the perturbative function in terms of the mean anomalies which is more commonly used. The result is partly given below. The formulas are more complicated than those in the case of a development in eccentric anomalies. But if we consider that it is necessary to pass from the latter development to one in terms of the mean anomalies by Besselian transformations, it will appear that the total reduction of work is fully as great in the present case as in that previously discussed. It may be well to state that the method given below applies as well to LEVERRIER's development as to that given by Professor NEWCOMB. The latter, however, presents an advantage for our purposes, namely, it fixes the place of each term in the development by certain indices, which facilitates the discovery of any relation which may exist between the different terms, while the place of a term in LEVERRIER's development is indicated by an irrelevant number. Therefore Professor NEWCOMB's development (*Astronomical Papers*, Vol. V, Part 1) has been selected for the application of the method as given below. It is to be hoped that with the present modification Professor NEWCOMB's development will gain another point over other similar developments.

Briefly stated the proposition is as follows:

The general term in the development of the perturbative function being of the form (*)

$$e^n e'^{n'} \mathrm{P}^{n,\,n'}_{m,\,m'} \cos(\mu\lambda + \nu\lambda' + m\zeta + m'\zeta')$$

we need only to compute directly those terms $\mathrm{P}^{n,\,n'}_{m,\,m'}$ *for which* $n = m$ *and* $n' = m'$. *The other terms are then readily obtained by means of linear expressions in the* $\mathrm{P}^{n,\,n'}_{n,\,n'}$ *with coefficients that are easily and quickly computed.*

By means of a similar process we may dispense with the direct computation of the derivatives $\mathrm{DP}^{n,\,n'}_{n,\,n'}$. Thus the heavy work of computation is reduced to only about one-fifth the number of coefficients.

The demonstration of the formulas given below, and the general expressions for computing the coefficients entering there will be given in full later, and at another place. Moreover, only a few of the total number of formulas are given here, as the work has not yet been fully accomplished.

First of all, we remark that as far as necessary for an illustration, we may restrict ourselves to terms of the form $\mathrm{P}^{n,\,0}_{m,\,0}$, because the symbol $\Pi^{n,\,n'}_{m,\,m'}$ is obtained by direct multiplication of the symbols $\Pi^{n,\,0}_{m,\,0}$ (or, simply, Π^{n}_{m}) and $\Pi^{0,\,n'}_{0,\,m'}$; and, on the other hand, the symbol $\Pi^{0,\,n}_{0,\,m}$ is obtained directly from Π^{n}_{m}, where μ and D are replaced by ν and $-(1+\mathrm{D})$. The symbol Π^{n}_{m} is an integral function of μ and D.

We have then to determine DP^{n}_{n} given P^{n+1}_{n+1}, P^{n}_{n}, P^{n-1}_{n-1}, ... the formulas

(*) e, ζ and λ are the eccentricity, mean anomaly and distance from the common node of the two planets for the inner; e' ζ' and λ' corresponding quantities for the outer planet. The coefficient $\mathrm{P}^{n,\,n'}_{m,\,m'}$ is the result of application of a symbolic expression $\Pi^{n,\,n'}_{m,\,m'}$ to certain coefficients; this symbolic expression is an integral function of μ, ν and D, the latter being the symbol for the derivative as to the logarithm of the mean distance of the inner planet.

(1) $$\mathrm{DP}^n_n = -2(n+1)\,\mathrm{P}^{n+1}_{n+1} + \sum_{k=0}^{k=n}\left(-\alpha_k\mu+\beta_k^{(n)}\right)\mathrm{P}^{n-k}_{n-k}$$

(2) $$\beta_k^{(n)} = 2(n-k)\,\beta_k$$

(3) $$\begin{cases}\alpha_k = -2(k+1)\,\beta_k \quad \text{for} \quad k>0\\ \alpha_0 = -2\end{cases}$$

A few of the coefficients α_k and β_k are given below. It is well to remark that an approximation up to the eighth power of the eccentricities requires the computation of only nine coefficients.

$$\begin{array}{lll|lll}\beta_0 &=& \frac{3}{2} & \beta_3 &=& -\frac{3}{128}\\ \beta_1 &=& -\frac{1}{8} & \beta_4 &=& -\frac{1}{60}\\ \beta_2 &=& -\frac{1}{24} & \beta_5 &=& -\frac{125}{(96)^2}\end{array}$$

From these we find

$$\begin{array}{lll|lll}\alpha_0 &=& -2 & \alpha_3 &=& \frac{3}{16}\\ \alpha_1 &=& \frac{1}{2} & \alpha_4 &=& \frac{1}{6}\\ \alpha_2 &=& \frac{1}{4} & \alpha_5 &=& \frac{125}{768}\end{array}$$

The coefficients $\mathrm{DP}^{n'}_{m'}$ where $n' \neq m'$ are expressed by means of the DP^n_n, DP^{n-1}_{n-1}, . . . in the same way as the $\mathrm{P}^{n'}_{m'}$ by means of the P^n_n, P^{n-1}_{n-1}, . . . Now a coefficient $\mathrm{P}^{n'}_{m'}$ where $n' \neq m'$ can always be thrown into the form P^{n+m}_{n-m} because $n'-m'$ is an even number. In this paper the general formulas are given only for $m=1$ and $m=2$. It is not necessary for practical purposes to go beyond $m=4$. The author has not yet established the relations for $m=3$ and $m=4$. The work is rather laborious, and requires much controlling of the results. The remaining two formulas will be given later. For $m=1$ we have

$$\mathrm{P}^{n+1}_{n-1} = (n+1)\,\mathrm{P}^{n+1}_{n+1} + \sum_{k=0}^{k=n}\left(-a_k\mu+b_k^{(n)}\right)\mathrm{P}^{n-k}_{n-k} \tag{4}$$

$$b_k^{(n)} = 2(n-k)\,b_k \tag{5}$$

$$\begin{cases}a_k = -2(k+1)\,b_k \quad \text{for} \quad k \neq 1\\ a_1 = -\frac{3}{4}\end{cases} \tag{6}$$

The coefficients a_k and b_k are given below up to $k=5$. Only eight coefficients need to be computed for all practical purposes.

$$\begin{array}{lll lll|lll lll}b_0 &=& -1 & b_3 &=& \frac{1}{48} & a_0 &=& 2 & a_3 &=& -\frac{1}{6}\\ b_1 &=& \frac{1}{4} & b_4 &=& \frac{9}{640} & a_1 &=& -\frac{3}{4} & a_4 &=& -\frac{9}{64}\\ b_2 &=& \frac{1}{24} & b_5 &=& \frac{1}{96} & a_2 &=& -\frac{1}{4} & a_5 &=& -\frac{2}{15}\end{array}$$

For $m=2$ we have the formula

$$\mathrm{P}^{n+2}_{n-2} = \frac{(n+2)(n+1)}{2}\,\mathrm{P}^{n+2}_{n+2} + 2(n+1)(-\mu-n)\,\mathrm{P}^{n+1}_{n+1} + \sum_{k=0}^{k=n}\left(\mathrm{A}_k\mu^2+\mathrm{B}_k^{(n)}+\mathrm{C}_k^{(n)}\right)\mathrm{P}^{n-k}_{n-k}$$

where
$$\mathrm{B}_k^{(n)} = \mathrm{B}_k + (n-k)\,\mathrm{B}'_k$$
$$\mathrm{C}_k^{(n)} = \frac{(n-k)(n-k-1)}{2}\,\mathrm{C}_k + (n-k)\,\mathrm{C}'_k$$

A few of these coefficients are given below.

$$\begin{array}{lll lll lll lll lll}\mathrm{A}_0 &=& 2 & \mathrm{B}_0 &=& +\frac{5}{4} & \mathrm{B}'_0 &=& -\frac{19}{4} & \mathrm{C}_0 &=& 5 & \mathrm{C}'_0 &=& \frac{1}{2}\\ \mathrm{A}_1 &=& -\frac{3}{2} & \mathrm{B}_1 &=& -\frac{1}{2} & \mathrm{B}'_1 &=& \frac{3}{4} & \mathrm{C}_1 &=& -\frac{11}{6} & \mathrm{C}'_1 &=& -\frac{1}{2}\\ \mathrm{A}_2 &=& -\frac{7}{32} & \mathrm{B}_2 &=& -\frac{1}{32} & \mathrm{B}'_2 &=& \frac{1}{8} & \mathrm{C}_2 &=& 0 & \mathrm{C}'_2 &=& 0\end{array}$$

To illustrate clearly the advantage of the present method over the direct computation of all the terms of the perturbative function the symbolic values of Π^6_4 and of $\mathrm{D}\Pi^5_5$ are given both as they appear in Professor Newcomb's development and as they are derived from the above formulas. Here $i = -\mu$.

(Newcomb)

$$\begin{aligned}7680\,\Pi^6_4 = {} & \mathrm{D}^6 + (8i-25)\,\mathrm{D}^5 + (20i^2-130i+185)\,\mathrm{D}^4 +\\ & + (-80i^2+340i-255)\,\mathrm{D}^3 + (-80i^4+640i^3-1765i^2+2280i-1466)\,\mathrm{D}^2\\ & + (-128i^5+1360i^4-5280i^3+9535i^2-8454i+3096)\,\mathrm{D}\\ & + (-64i^6+800i^5-3740i^4+8200i^3-8588i^2+3608i)\end{aligned}$$

(Chessin)

$$\Pi^6_4 = 6\,\Pi^6_6 + 2(i-5)\,\Pi^5_5 - (\tfrac{3}{4}i-2)\,\Pi^4_4 - (i-\tfrac{1}{4})\,\Pi^3_3 - \tfrac{1}{12}(2i-1)\,\Pi^2_2 - \tfrac{9}{320}(5i-1)\,\Pi^1_1 - \tfrac{2}{15}\,i$$

(Newcomb)

$$\begin{aligned}3840\,\mathrm{D}\Pi^5_5 = {} & -\mathrm{D}^6 + (-10i+30)\,\mathrm{D}^5 + (-40i^2+230i-305)\,\mathrm{D}^4 +\\ & + (-80i^3+660i^2-1660i+1220)\,\mathrm{D}^3 +\\ & + (-80i^4+840i^3-2995i^2+4080i-1569)\,\mathrm{D}^2\\ & + (-32i^5+400i^4-1790i^3+3360i^2-2194i)\,\mathrm{D}\end{aligned}$$

(Chessin)

$$\mathrm{D}\Pi^5_5 = -12\,\Pi^6_6 + (-2i+15)\,\Pi^5_5 + (\tfrac{1}{2}i-1)\,\Pi^4_4 + \tfrac{1}{4}(i-1)\,\Pi^3_3 + \tfrac{3}{32}(2i-1)\,\Pi^2_2 + \tfrac{1}{30}(5i-1)\,\Pi^1_1 + \tfrac{125}{768}\,i$$

The illustration would be still more conspicuous for Π^7_5, Π^8_6, $\mathrm{D}\Pi^6_6$, $\mathrm{D}\Pi^7_7$, . . . and so on. As seen from these examples the reduction of work in computing P^{n+1}_{n-1} is due to replacing polynomials of degrees as high as $(n+1)$ by others of the first degree. In general, this method enables to substitute for polynomials of degree $n+m$ which appear in Prof. Newcomb's expression for the symbol Π^{n+m}_{n-m}, other polynomials of degree m. The advantage gained is obvious. It is the greater the lesser the number m. As to computing the DP^n_n our method enables us to substitute linear expressions in i for polynomials of the order as high as n.

New York, 1898 *July*.

NOTES ON SOUTHERN VARIABLE STARS,

By R. T. A. INNES.

[Communicated by DAVID GILL, H.M. Astronomer.]

The following results of recent observations of variable stars may prove interesting. The observations will be published in full in the 3d volume of the *Cape Photographic Durchmusterung*, which is now in the press.

With one exception (*RS Centauri*) all these stars are taken from lists forwarded from time to time by Professor KAPTEYN.

C.Z. II, 1547 (1875) $2^h 56^m 52^s$ $-51° 8'.2$.

See *C.P.D.*, Vol. I, page (93) [*Cape Annals*, Vol. III]. Forty-three visual observations, between 1897 Nov. 26 and 1898 June 8, yield a good maximum = $8^M.1$ on 1898 Jan. 29. Minimum between 1898 April 20 May 16, when the star was invisible. Period 200 days ±.

T Leporis (1875) $4^h 59^m 30^s.8$ $-22° 4'.4$.

Maximum 1897 Dec. 7; magnitude = 8.3; redness = 7.9; invisible on 1898 May 26. A halt occurs on the way to minimum at 100 to 120 days after maximum.

List in *Astr. Nachr.* 3441, No. 2 (1875) $8^h 8^m 16^s$ $-34° 12'.1$.

Max.	1897 May 14, June 28, Dec. 9 1898 Jan. 15, Feb. 28	$6^M.8 \pm 0^M.2$
Min.	1897 June 12 1898 Jan. 2, Feb. 17	$7^M.8 \pm 0^M.2$

Color = 4.3.

A period of $41^d.05$ will represent all observations back to 1849 within reasonable limits. A halt or slackening of decrease for 4 days always occurs about 8 days after maximum. The rise from minimum is very quick, about 10 days.

List in *Astr. Nachr.* 3426, No. 11 (1875) $9^h 39^m 16^s$ $-23° 26'.7$.

1897. Invisible Feb. 25–May 22; $10^M.3$ to $11^M.8$ between June 12–July 13; invisible August and December.

1898. Invisible January–April.

17 May	= $10^M.3$	13 other confirmatory observations.
19 "	= 10.25	
31 "	= 9.7	
9 June	= 9.65	
30 "	= 9.55	

Period perhaps about 350 days.

Astr. Nachr. 3441, No. 3 (1875) $10^h 45^m 22^s$ $-27° 58'.2$.

A fair maximum occurred on 1897 April 22, a good maximum on 1898 March 31, each about $8^M.5$. A period of about 339 days will satisfy Cordoba observations in 1886, 1888 and 1891. At minimum the star is below 11^M, and invisible in the 7-inch. The color is very slight, nearly white, say = 0.5.

RS Centauri (1875) $11^h 15^m 5^s \pm$ $-61° 12'.6 \pm$.

This was picked up by chance on 1898 March 21, when it was $8^M.5$, reddish; by the end of May it was 11^M to $11^M.5$, and has been invisible since June; last obsn. = July 4.

Cord. DM. −32°8314 (1875) $11^h 41^m 22^s$ $-32° 34'.5$.

Prof. KAPTEYN cannot find this star on *C.P.D.* plates. THOME gives = $8^M.5$. Certainly variable, $8^M.9$ to $9^M.55$, from observations 1897–8; the period may be about 60 days; color = 3.

RT Centauri (1875) $13^h 41^m 2^s$ $-36° 14'.2$.

Invisible from 1897 Aug. 28–Sept. 17; afterwards too near Sun for further evening observation in 1897. A good minimum was observed on 1898 May 23, about $11^M.2$.

Oe. Arg. 13441 (1875) $14^h 4^m 22^s$ $-28° 17'.6$.

This star is generally invisible; the last observation in 1897 before it was lost in daylight, was on September 24, when it had attained $8^M.8$.

1898 March 11–May 7 invisible. May 15–June 1 glimpsed with difficulty, $11^M.5$ to 12^M. Invisible after June 8.

R Normae (*C.G.A.*) (1875) $15^h 26^m 58^s$ $-49° 5'.2$.

Although GOULD's observations put the variability of this star beyond all reasonable doubt, the name *R Normae* has since been applied to another star.

Maximum 1897 Sept. 6 = $6^M.9$; color about 7.0.

1898 Feb. 13 = $10^M.5$, Mar. 11 = $10^M.8$, Apr. 4 = $10^M.7$, May 2 = $9^M.6$, May 30 = $8^M.4$, June 30 = $7^M.75$.

C.Z. XV, 3719 (1875) $15^h 52^m 56^s$ $-29° 33'.9$.

Prof. KAPTEYN does not find this star on the *C.P.D.* plates. Generally this star is of the $9^M.1$, and it descends very quickly to a minimum of about $10^M.7$. Such minima occurred on 1896 Sept. 5 and 1898 May 5. A period of 608 days will satisfy all minima observed so far; no integral division of this period will suit observations in 1897. There is a halt and going back, on return to normal brightness, otherwise it would have been pronounced an *Algol*-variable.

RZ Scorpii (1875) $15^h 57^m 8^s$ $-23° 45'.2$.

A poor maximum of about $9^M.4$ occurred in 1897 September. On 1897 Oct. 19 it was under 10^M (not seen). The last observations 1898 June 25 and 30 give $8^M.9$. Period 135 days ±.

C.Z. XVI, 1980 (1875) $16^h 28^m 39^s$ $-30° 58'.5$.

Cordoba $8^M.9$–$9^M.0$. *C.P.D.* nil.

1896 May 7–Oct. 20	9.3 to 9.7	Color = 6.9
1897 June 1–Oct. 19	7.8 to 9.3	
1898 May 16–June 30	7.8 to 9.0	

Has a *comes* 11^M s.f.

C.Z. XVI, 2278 (1875) $16^h 32^m 36^s$ $-32° 7'.9$.

Cordoba $7^M.5$–$8^M.5$–$9^M.0$.

1896 about	8.8	Color = 9.1.
1897 "	8.8	
1898 "	8.0 to 8.4	

Probably variable — the reddest star I know.

Royal Observatory, Cape of Good Hope, 1898 *July* 7.

C.P.D. Vol. I, p. (93) (1875) $16^h 41^m 43^s$ $-19° 14'.3$.

W.Z. = $9^M.0$; Schönfeld = $8^M.8$; Porter = $8^M.5$; *C.P.D.* = $9^M.2$ to inv.

1898 May 13 = $11^M.5$ June 1 = $9^M.75$ June 30 = $8^M.7$. Color = 3.

RS Scorpii (1875) $16^h 46^m 34^s$ $-44° 53'.7$.

1897 July 27–Oct. 23	$10^M.4$ to inv.
1898 May 16–June 22	$9^M.1$ to $10^M.1$

C.Z. XVI, 911 (1875) $16^h 12^m 48^s$ $-63° 44'.6$.

C.Z. = $10^M.0$. *C.P.D.* nil (2 obs.). 1898 May 27–June 30, $8^M.2$–$8^M.5$. Color = 3.3.

Although my observations alone prove nothing, the three previous observations make variability certain.

OBSERVATIONS OF THE SATELLITES OF *URANUS*.

By R. G. AITKEN.

The following measures of the satellites of *Uranus* were made with the 36-inch refractor of the Lick Observatory. A power of 520 was used except on the nights of April 22 and May 29, when powers of 350 and 270, respectively, were employed. For March 27, the printed measures are the means of three measures of position-angle and of four measures of distance. For all other nights the means represent five settings of the micrometer in each coordinate.

The two outer satellites seemed to be sensibly equal in brightness and no noticeable variations were recorded. Of the two inner satellites, *Umbriel* was found to be considerably fainter than *Ariel* — too faint, in fact, to measure on two nights when *Ariel* was measured — except on April 22, on which night *Ariel* was noted as the fainter of the two.

Ariel.

1898	Pacific Standard Time h m s	Position Angle °	Distance ″
*Apr. 8	15 33 9	19.7	. .
22	15 37 44	219.0	. .
22	15 49 29	. .	13.88
24	14 2 27	135.1	. .
24	14 9 16	. .	14.12
May 29	10 58 37	77.6	. .
29	11 7 1	. .	13.71
June 4	10 48 57	212.8	. .
4	10 57 35	. .	14.50
5	11 16 46	358.9	. .
5	11 23 50	. .	14.39
17	11 8 13	270.9	. .
17	11 15 29	. .	14.26
July 3	10 30 10	33.5	. .
3	10 38 36	. .	13.71

* Wind prevents distance measures.

Umbriel.

1898	Pacific Standard Time h m s	Position Angle °	Distance ″
Apr. 8	16 0 2	218.2	. .
22	15 0 23	350.6	. .
22	15 10 21	. .	19.99
24	14 22 32	160.5	. .
24	14 29 13	. .	20.37
June 5	10 49 40	197.2	. .
5	11 1 43	. .	20.66
17	10 52 24	161.1	. .
17	11 0 21	. .	20.56
July 3	10 13 46	110.8	. .
3	10 21 22	. .	19.29
14	8 47 50	340.2	. .
14	8 56 56	. .	19.19

Titania.

1898	Pacific Standard Time h m s	Position Angle °	Distance ″
Mar. 27	16 45 1	85.8	. .
27	16 50 1	. .	31.84
27	16 53 39	85.6	. .
Apr. 8	15 43 33	218.2	. .
22	14 26 14	76.7	. .
22	14 31 38	. .	31.98
24	14 41 0	158.1	. .
24	14 35 42	. .	33.62
May 29	11 35 48	162.1	. .
29	11 43 28	. .	33.60
June 4	11 15 18	48.0	. .
4	11 23 43	. .	32.28
5	11 29 28	91.0	. .
5	11 35 24	. .	32.70
17	11 20 41	225.7	. .
17	11 27 31	. .	32.59
July 3	10 57 16	167.8	. .
3	11 2 32	. .	33.35

Oberon.

1898	Pacific Standard Time	Position Angle	Distance
	h m s	°	″
Mar. 27	16 57 29	12.6	. .
27	17 1 57	. .	43.20
27	17 7 17	12.2	. .
Apr. 8	15 51 46	331.3	. .
22	14 38 12	345.3	. .
22	14 45 31	. .	44.05
24	14 49 14	38.4	. .
24	14 56 0	. .	43.28
May 29	11 20 56	251.2	. .

Oberon. — Cont.

1898	Pacific Standard Time	Position Angle	Distance
	h m s	°	″
May 29	11 29 19	. .	43.80
June 1	11 30 28	. .	42.87
1	11 37 34	52.1	. .
5	11 46 20	80.3	. .
5	11 53 29	. .	43.46
17	10 40 7	37.9	. .
17	10 45 44	. .	43.62
July 3	10 45 26	108.7	. .
3	10 50 48	. .	42.91

Lick Observatory, University of California, 1898 *July* 25.

THE PROPER MOTION OF DM. +18°3423 AND +18°3424,

By J. G. PORTER.

For the star 6369 in AUWERS's A.G. Catalogue, there is given a proper motion of $-0^s.063$ and $+0''.88$, or $1''.25$ in a great circle. This motion is derived from one Bonn observation, the observation of the A.G. Catalogue, and a recent Berlin observation. But from a note it appears that the second of these observations received a double correction, $+24^s.15$, on the assumption that the transits were taken over tally *a* instead of tally *b*, and then an arbitrary correction of $+10^s$. That this should place the star exactly between the Bonn position and the modern Berlin place is a very strange coincidence; for, as a matter of fact, this star has little motion, and the corrected observation pertains to a different star.

The positions which I have been able to collect for the star in question = DM. +18°3424, are as follows, reduced to 1875.0:

		h m s	° ′ ″
Bonn VI	1856.5	17 33 15.75	+18 37 40.1
Vienna Zone	1858.5	13.08	38 20.2
[Berlin A.G. 6369,	1869.6	17 33 14.78	+18 37 55.4]
Battermann	1895.5	13.20	38 14.6
Cincinnati	1898.0	13.21	38 14.3

The bracketed position, as I shall show, belongs to another star. The Cincinnati position, which is the mean of four observations, compared with that of BATTERMANN, makes it evident that no large motion exists. Hence it is all but certain that the Vienna place is correct and the Bonn observation erroneous.

If after correcting the star 6369 $+24^s.15$ for the tally, we subtract 10^s instead of adding, there results the position $17^h\,32^m\,54^s.78$ $+18°\,37'\,55''.4$. In exactly this place there is a 9.5-magnitude star, an approximate equatorial comparison giving $17^h\,32^m\,54^s.7$ $+18°\,37'\,57''$. There can then be little doubt that this was the star really observed.

It is perhaps worth noticing that another star of this same group, namely DM. +18°3423 has an appreciable motion of $-0^s.011$ and $-0''.21$.

EPHEMERIS OF COMET *c* 1898 (*CODDINGTON*).

By E. F. CODDINGTON.

From my elements, given in *A.J.* No. 441, I have computed the following ephemeris of this comet. These elements give the following residuals for an observation of July 14: O−C, $\Delta\alpha = -1^s.68$, $\Delta\delta = +7''.8$. The brightness at discovery is taken as unity.

Gr. M.T.	True α	True δ	log Δ	Br.
1898	h m s	° ′ ″		
Aug. 13.5	13 43 33.6	−50 43 48	0.1836	0.73
17.5	13 40 31.7	−51 47 5	0.1951	0.70
21.5	13 38 14.1	−52 51 19	0.2060	0.68
25.5	13 36 38.0	−53 57 1	0.2161	0.65
29.5	13 35 40.1	−55 4 28	0.2256	0.63
Sept. 2.5	13 35 18.9	−56 13 59	0.2345	0.61
6.5	13 35 32.6	−57 25 48	0.2426	0.59
10.5	13 36 20.9	−58 40 9	0.2501	0.57
Sept. 14.5	13 37 43.6	−59 57 17	0.2569	0.55
18.5	13 39 41.2	−61 17 26	0.2632	0.54
22.5	13 42 14.7	−62 40 43	0.2688	0.52
26.5	13 45 26.6	−64 7 16	0.2738	0.51
30.5	13 49 20.1	−65 37 10	0.2781	0.49
Oct. 4.5	13 54 1.8	−67 10 30	0.2824	0.48
8.5	13 59 40.6	−68 47 16	0.2860	0.47
12.5	14 6 29.5	−70 27 30	0.2892	0.45
16.5	14 14 47.2	−72 11 7	0.2920	0.44
20.5	14 25 2.5	−73 57 47	0.2945	0.43
24.5	14 38 0.2	−75 47 00	0.2968	0.42
28.5	14 54 54.6	−77 37 47	0.2988	0.41
Nov. 29.5	23 9 13	−80 21 11	0.3156	0.31
Dec. 31.5	1 29 5	−58 35 33	0.3557	0.20

Lick Observatory, Mt. Hamilton, Cal., 1898 *July* 22.

OBSERVATIONS OF COMET 1896 I,

MADE WITH THE 12-INCH REFRACTOR OF THE LICK OBSERVATORY,

By WILLIAM J. HUSSEY.

1896 Mt.Hamilton M.T.	*	No. Comp.	☌' — * $\Delta\alpha$	☌' — * $\Delta\delta$	☌'s apparent α	☌'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			m s	″	h m s	° ′ ″		
March 6 8 1 38	1	8, 12	−0 26.42	+2 51.9	2 2 39.61	+51 10 36.9	9.856	0.281
8 4 43	3	12, 12	−1 39.17	+3 3.6	2 2 41.57	+51 10 32.2	9.859	0.300
8 47 0	1	1	0 0.00	. . .	2 3 6.03	. . . .	9.805	. .
10 8 20 53	4	10, 8	−1 48.18	+1 47.8	2 47 31.16	+49 24 20.7	9.836	0.272
8 20 53	5	10	+1 6.13	. . .	2 47 31.03	. . . .	9.836	.
12 9 58 11	6	4	. . .	+8 10.8	. . . .	+48 26 53.4	. .	0.599
16 8 13 27	7	4	. . .	+2 20.1	. . . .	+46 47 15.3	. .	0.211
23 8 44 16	8	5	. . .	−0 2.9	. . . .	+44 27 12.8	. .	0.402
9 32 21	8	3	−0 42.67	. . .	3 54 4.47	. . . .	9.815	. .
29 8 18 18	9	16, 9	−3 47.33	+0 24.3	4 9 28.08	+42 59 49.1	9.779	0.356
30 7 33 14	10	8	. . .	+2 14.8	. . . .	+42 47 53.5	. .	0.168
7 50 57	10	6	−1 53.60	. . .	4 11 37.48	. . . .	9.757	. .
31 8 5 42	10	10, 15	+0 14.89	−9 51.3	4 13 45.95	+42 35 47.3	9.770	0.329
April 1 9 2 15	11	13, 11	−1 13.89	−1 46.3	4 15 52.18	+42 23 57.9	9.797	0.520
2 8 50 18	12	11, 18	+0 10.35	+5 17.1	4 17 48.51	+42 13 25.3	9.793	0.495
3 8 17 43	13	6, 12	+0 48.82	+4 8.8	4 19 40.04	+42 3 13.4	9.778	0.403
6 9 41 55	14	3	. . .	−0 24.4	. . . .	+41 34 15.4	. .	0.645
10 5 22	14	8	+3 45.54	. . .	4 25 7.66	. . . .	9.782	. .

Mean Places for 1896.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	2 3 6.69	−0.66	+51 7 29.2	+15.8	DM. +50°462, connected with *2
2	2 3 7.75	−0.66	+51 10 18.0	+15.8	Rodgers, Cambridge A.G. Catal. 998
3	2 4 21.40	−0.66	+51 7 12.8	+15.8	" " " " 1009
4	2 49 19.53	−0.19	+49 22 15.7	+17.2	Deichmüller, Bonn Catal. 2488
5	2 46 25.12	−0.22	+49 22 24.6	+17.1	" " " 2457
6	3 7 39.30	−0.02	+48 18 25.2	+17.4	" " " 2709
7	3 28 39.78	+0.09	+46 44 37.9	+17.3	" " " 3023
8	3 54 46.83	+0.31	+44 26 59.4	+16.3	" " " 3320
9	4 13 15.04	+0.37	+42 59 10.2	+14.6	" " " 3551
10	4 13 30.72	+0.36	+42 45 23.3	+15.4	" " " 3554
11	4 17 5.72	+0.35	+42 25 29.1	+15.1	" " " 3585
12	4 17 37.80	+0.36	+42 7 53.3	+14.9	" " " 3592
13	4 18 50.85	+0.37	+41 58 49.8	+14.8	" " " 3609
14	4 21 21.76	+0.36	+41 34 25.4	+14.4	" " " 3633

On March 30, April 1, 2, and 3, $\Delta\alpha$ was measured directly with the micrometer: on other dates it was obtained by transits. March 30 was windy, and $\Delta\alpha$ is somewhat uncertain. The following changes result from a re-reduction of my observations of this comet given in *A.J.* 371. On March 9 $\Delta\delta$ should read $-28''.1$; for *6 seconds of δ should read $46''.4$; and the date of the second observation of March 13 should be increased 1^{m}.

Mt. Hamilton, Cal., 1898 *August* 4.

OBSERVATIONS OF COMET *c* 1898 (CODDINGTON),

MADE WITH THE 20-INCH EQUATORIAL OF THE CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, COLORADO,

By HERBERT A. HOWE.

The following observations were made with the new micrometer provided by the liberality of Miss CATHERINE W. BRUCE. It has been constructed by Mr. SAEGMULLER, with special reference to rapid work in determining $\Delta\alpha$ and $\Delta\delta$. There are eleven R.A. wires, and nine accurately spaced micrometer-wires. The wires can be illuminated simultaneously or separately, each set with any desired intensity. The box can be turned 90° without looking at the position-circle. The micrometer-screw carries three divided heads, two of which are movable. The extreme micrometer-wires are 30′ apart. This micrometer has been tested by six months' observing on nebulas, and has shown itself to be a most admirable instrument.

University Park M.T.		*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
1898	h m s			m s	′ ″	h m s	° ′ ″		
June 20	10 21 22	1	10 , 6	+ 0 6.17	+ 3 13.2	15 53 39.38	−30 49 35.8	8.765	0.917
	11 16 16	2	16 , 6	+ 4 19.27	− 3 38.3	15 53 30.90	−30 50 57.8	9.259	0.907
	11 39 29	3	16 , 6	− 3 5.56	−11 52.6	15 53 27.69	−30 51 32.8	9.363	0.899
22	10 39 40	4	16 , 4	+ 1 7.75	+ 7 37.6	15 46 27.55	−32 0 27.3	9.132	0.915
	11 7 56	5	18 , 6	− 1 22.10	+ 2 34.0	15 46 23.29	−32 1 5.4	9.297	0.907
	11 46 28	6	20 , 6	+ 3 29.45	+12 46.6	15 46 17.25	−32 2 2.5	9.445	0.892
23	9 51 58	7	20 , 5	− 0 21.06	− 3 45.4	15 43 0.13	−32 33 44.1	8.635	0.922
	10 15 30	8	20 , 6	+ 1 36.97	− 8 51.3	15 42 56.72	−32 34 19.7	8.991	0.919
	10 47 30	9	20 , 6	− 2 18.29	−12 7.4	15 42 51.87	−32 35 3.7	9.233	0.912
24	9 56 30	10	20 , 6	+ 2 21.74	− 2 34.4	15 39 24.95	−33 7 40.8	8.855	0.922
	10 13 47	11	20 , 6	− 2 17.97	+ 2 58.9	15 39 22.46	−33 8 5.0	9.049	0.920
	10 31 56	12	20 , 5	+ 0 36.34	+ 1 27.4	15 39 19.63	−33 8 29.3	9.187	0.916
25	10 46 33	13	20 , 6	+ 1 35.99	+13 5.2	15 35 44.01	−33 41 59.7	9.310	0.910
	11 2 29	14	20 , 6	− 3 3.65	+ 7 45.6	15 35 41.51	−33 42 25.3	9.378	0.905
	11 22 44	15	20 , 6	−10 10.09	+ 6 6.9	15 35 38.40	−33 42 49.9	9.449	0.896
27	10 33 58	16	20 , 6	+ 1 22.79	+15 10.4	15 28 41.04	−34 46 22.2	9.327	0.912
	10 52 33	17	20 , 6	−10 0.62	+ 0 16.0	15 28 38.35	−34 46 48.1	9.403	0.905
	11 21 14	18	20 , 6	− 9 15.17	+10 10.2	15 28 34.05	−34 47 25.6	9.494	0.891
28	11 19 8	19	20 , 8	+ 0 25.51	− 1 0.5	15 25 3.64	−35 18 38.8	9.512	0.889
	11 35 36	20	20 , 8	− 0 22.76	− 6 46.6	15 25 1.26	−35 18 56.5	9.552	0.879
30	8 55 4	21	20 , 6	− 1 21.58	− 1 44.6	15 18 28.64	−36 16 20.1	8.519	0.930
	9 10 23	22	20 , 6	− 1 10.79	− 9 29.5	15 18 26.42	−36 16 38.4	8.849	0.929
	9 27 30	23	20 , 6	− 2 26.29	+ 7 53.6	15 18 24.22	−36 17 0.5	9.050	0.926
July 5	9 26 31	24	10 , 3	− 1 56.41	−12 31.7	15 1 42.65	−38 37 1.9	9.304	0.921
8	8 53 43	25	20 , 6	− 2 31.09	+ 1 41.5	14 52 20.03	−39 52 46.7	9.248	0.926
	9 18 29	26	20 , 6	+ 4 14.22	+ 3 51.9	14 52 16.50	−39 53 14.5	9.374	0.918

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 53 28.92	+4.29	−30 52 33.1	−15.9	Gould, Gen. Catal. 21664
2	15 49 7.37	+4.26	−30 47 3.2	−16.3	" Gen. Catal. 21557
3	15 56 28.95	+4.30	−30 39 24.6	−15.6	" Gen. Catal. 21727
4	15 45 15.51	+4.29	−32 7 47.8	−17.1	" Zone Catal. 15h3084
5	15 47 41.09	+4.30	−32 3 22.6	−16.8	" Zone Catal. 15h3237
6	15 42 43.52	+4.28	−32 14 31.8	−17.3	" Gen. Catal. 21417
7	15 43 16.91	+4.28	−32 29 41.3	−17.4	" Gen. Catal. 21432
8	15 41 15.48	+4.27	−32 25 10.8	−17.6	" Gen. Catal. 21380
9	15 45 5.87	+4.29	−32 22 39.2	−17.1	" Gen. Catal. 21473
10	15 36 58.96	+4.25	−33 4 48.3	−18.1	" Gen. Catal. 21293
11	15 41 36.14	+4.29	−33 10 46.2	−17.7	" Gen. Catal. 21390
12	15 38 39.02	+4.27	−33 9 38.7	−18.0	" Zone Catal. 15h2591
13	15 34 3.77	+4.25	−33 54 46.3	−18.6	" Zone Catal. 15h2248
14	15 38 40.88	+4.28	−33 49 52.7	−18.2	" Zone Catal. 15h2592
15	15 45 44.16	+4.33	−33 48 39.3	−17.5	" Gen. Catal. 21486
16	15 27 14.03	+4.22	−35 1 13.1	−19.5	" Zone Catal. 15h1754
17	15 38 34.67	+4.30	−34 46 45.7	−18.4	" Gen. Catal. 21329
18	15 37 44.92	+4.30	−34 57 17.3	−18.5	" Gen. Catal. 21315
19	15 24 33.92	+4.21	−35 17 18.5	−19.8	" Gen. Catal. 21003
20	15 25 19.81	+4.21	−35 11 50.2	−19.7	" Zone Catal. 15h1628
21	15 19 46.02	+4.20	−36 14 15.1	−20.4	" Gen. Catal. 20892
22	15 19 33.02	+4.19	−36 6 48.5	−20.4	" Gen. Catal. 20882
23	15 20 46.30	+4.21	−36 24 33.7	−20.4	" Gen. Catal. 20909
24	15 3 34.91	+4.12	−38 24 7.5	−22.7	" Gen. Catal. 20546
25	14 54 47.08	+4.04	−39 54 4.3	−23.9	" Zone Catal. 14h3392
26	14 47 58.31	+3.97	−39 56 12.0	−24.1	" Gen. Catal. 20169

OBSERVATIONS OF COMET 1898 *c* (*CODDINGTON*),

MADE AT THE LICK OBSERVATORY,

BY E. F. CODDINGTON.

1898 Mt. Hamilton M.T.	*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			m s	″	h m s	° ′ ″		
June 12 9 22 51	1	10 , 8	−4 9.95	−5 3.6	16 21 34.06	−25 52 43.4	n9.309	0.880
13 10 5 25	2	10 , 10	−0 24.01	+2 35.9	16 18 5.02	−26 31 48.2	n8.984	0.892
14 8 55 9	3	10 , 8	−0 17.10	−8 24.5	16 14 49.35	−27 7 52.1	n9.368	0.880
16 10 38 6	4	10 , 10	−0 8.77	−2 25.9	16 7 37.49	−28 25 34.1	8.467	0.903
17 11 51 46	6	8 , 8	−0 11.89	−3 30.8	16 3 55.31	−29 4 37.5	9.329	0.890
18 10 2 8	7	8 , 8	−0 5.60	−5 22.1	16 0 39.91	−29 38 30.9	n8.203	0.907
23 9 1 46	8	8 , 8	−0 23.63	−4 8.7	15 42 57.56	−32 31 7.4	n8.934	0.914
24 9 5 38	9	8 , 8	+0 39.62	+1 54.6	15 39 22.91	−33 8 2.1	n8.693	0.917
26 9 7 51	10	7 , 10	−0 46.84	+4 17.4	15 32 15.65	−34 13 57.2	n7.869	0.921

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 25 39.79	+4.22	−25 47 27.7	−12.1	Gould's General Catal. 22365
2	16 18 24.81	+4.22	−26 34 11.3	−12.8	Gould's General Catal. 22226
3	16 15 2.23	+4.22	−26 59 14.4	−13.2	Gould's Zone-Catal. 16h962
4	16 7 42.01	+4.25	−28 22 54.2	−14.0	13M connected with *5
5	16 11 58.33	+4.27	−28 21 34.8	−13.6	½[Gould's Gen.Catal.22078 + Stone's Radc.4222]
6	16 4 2.94	+4.26	−29 0 52.2	−14.5	Gould's General Catal. 21900
7	16 0 41.24	+4.27	−29 32 53.9	−14.9	Gould's Zone-Catal. 15h4140
8	15 43 16.91	+4.28	−32 29 41.3	−17.4	Gould's General Catal. 21432
9	15 38 39.02	+4.27	−33 9 38.7	−18.0	Gould's Zone-Catal. 15h2591
10	15 32 58.24	+4.25	−34 17 55.8	−18.8	Gould's General Catal. 21198

$\Delta\alpha$ for the first observation was obtained by transits and for all other dates by direct micrometer-comparisons.

The observations of June 16 and 23 were made with the 36-inch and all others with the 12-inch telescope.

Mt. Hamilton, 1898 *Aug.* 12.

EPHEMERIS OF WOLF'S PERIODIC COMET = *f* 1898,

BY A. THRAEN.

(*A.N.* 3506) : For Berlin Midnight.

1898	α	δ	log Δ	Br.
	h m s	° ′		
Aug. 22.5	5 22 52	+14 29.5	0.2417	2.5
23.5	25 13	14 16.9		
24.5	27 34	14 3.3	0.2393	
25.5	29 54	13 49.6		
26.5	32 13	13 35.7	0.2368	2.5
27.5	34 31	13 22.0		
28.5	36 46	13 8.2	0.2344	
29.5	39 0	12 53.9		
30.5	5 41 13	+12 39.5	0.2320	2.5
Aug. 31.5	5 43 25	+12 24.8		
Sept. 1.5	45 36	12 10.0	0.2296	
2.5	47 46	11 55.0		
3.5	49 53	11 39.8	0.2271	2.6
4.5	51 59	11 24.3		
5.5	54 5	11 8.8	0.2247	
6.5	56 10	10 53.0		
7.5	5 58 12	+10 37.1	0.2222	2.6

Brightness May 1 taken as unity.

NEW ASTEROID.

Prof. KREUTZ communicates the discovery of a new asteroid, by CHARLOIS, on July 16, and the position,

DP 11M 1898 July 18 11h 6m.5 Nice M.T. $\alpha = 20^h\,10^m\,8^s.2$, $\delta = -10°\,15'\,51''$. Daily motion -52^s and 5′ northward.

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OBSERVATIONS OF *TITAN-IAPETUS*, AND THE MASS OF *SATURN*.

BY PROF. STIMSON J. BROWN, U.S.N.

[Communicated by Prof. WM. HARKNESS, U.S.N., Astronomical Director.]

The values of the mass of *Saturn* derived by Prof. A. HALL from his extensive observations of the satellites of that planet, differ from each other by amounts many times greater than the probable errors of the separate results, while the most probable mean of the values derived from *Titan* and *Iapetus* is equally divergent from those derived by other observers using different instruments and methods of observation. The results of BESSEL and A. HALL, JR., from heliometer observations of *Titan*, and those of H. STRUVE from differential observations of *Titan–Iapetus* with the 30-inch Pulkowa refractor, agree fairly with the value deduced by GEO. W. HILL from the perturbative effect of *Saturn* on *Jupiter*.

The inherent difficulty of referring observations of the satellites, either with the filar micrometer or by differences of right-ascension and declination, to a body of such irregular shape as *Saturn's*, led me to attempt a re-determination of the mass with the 26-inch telescope, using the method of differential observations of *Titan–Iapetus*.

In the discussion of his observations by this method H. STRUVE has presented an exhaustive treatment of the general subject, showing that this method of obtaining the elements of two satellites is not attended with an appreciable loss of accuracy in the determination of their mean distances, although some of the other elements are subject to considerable diminution in their weights. All my observations of *Saturn's* satellites have been made on this plan, and consist of combination-observations of *Titan–Iapetus*, *Rhea–Dione*, *Tethys–Enceladus*.

Although the elevating floor was not yet in thorough working order, observations were begun with the 26-inch telescope of this observatory on April 23, 1894, and continued on every clear night during that opposition as well as the succeeding ones of 1895–6. Owing to unfavorable observing weather, only twenty-five complete observations of *Titan–Iapetus* were secured at each opposition, although several nights were utilized when observations requiring steadiness of image were impossible. There were but few nights on which the seeing was noted as good, while *Hyperion* was seen only three or four times, and *Mimas* only once during the three years. During much of the time difficult double-star measurements, requiring high magnifying powers, were out of the question. I think, however, that such unsteadiness of image does not greatly influence the accuracy of differential measurements of right-ascension and declination.

Differences of right-ascension and declination between *Titan* and *Iapetus* were observed, except when both bodies were near conjunction together, in which case position-angle and distance of *Iapetus* relative to *Titan* were obtained. The fixed wire and the movable micrometer-wire, set about two seconds of time apart, were used in observing the transits in right-ascension which were recorded on the chronograph. Whenever possible twenty transits over the two wires were observed, ten preceding and ten following the five or more differences of declination. The old Clark-micrometer with a magnifying power of 383 was used in all the observations, and the wires were illuminated with a small hand-lamp which threw a beam of red light through a small opening in the end of the micrometer-box opposite the micrometer-head. This arrangement is the same as that used by Prof. HALL in all his work with this instrument. It is open to the serious objection that it gives an unsymmetrical illumination of the thread, but is yet very convenient when the intensity of the thread-illumination has to be quickly and decidedly varied. This was often the case when *Iapetus*, at or near eastern elongation, was exceedingly faint.

The table of observations following contains the exact records of the observing books, with the exception of the column "total correction" which contains the sum of all the corrections to be applied to the observed quantities. It is placed here in order to avoid crowding the table of "computed quantities."

Observations of *Titan–Iapetus.*

Date	W.M.T.	$\alpha_1 - \alpha_2$	Total Corr.	No.	W.M.T.	$\delta_1 - \delta_2$ Mic. Read.	Total Corr.	No.	Mic. Zero	Parallel	Image	
1894	h m				h m	r	"					
Apr. 23	10 22.7	− 17ˢ.583	−0″.01	20	10 26.6	+81.696	+0.10	10	64.218	178.68	3	
25	9 6.7	p257°.906	−0°.099	10	9 3.0	+82.375	+0.12	5	64.200	177.78	3	
26	10 3.5	+ 5ˢ.862	+0″.02	20	10 3.8	+47.699	+0.10	6	. . .	178.07	3	
30	10 25.8	+ 19 .908	+0 .05	26	10 25.8	+57.676	+0.01	5	64.251	177.58	3	
May 1	9 25.6	+ 18 .764	+0 .05	40	9 25.3	+59.959	+0.03	5	64.246	177.62	3	
12	10 46.5	+ 42 .800	+0 .06	40	10 47.0	−68.157	−0.06	7	64.239	177.87	3	
13	9 54.8	+ 46 .589	+0 .10	40	9 55.1	−65.387	+0.02	6	. . .	. . .	3	Changed micrometer 5 rev. [*Iapetus* faint
14	9 23.7	+ 48 .557	+0 .12	14	9 24.1	−72.821	+0.01	8	. . .	177.84	3	*Iapetus* faint
15	10 13.8	+ 48 .129	+0 .12	32	10 16.2	−75.519	0.00	6	. . .	. . .	4	
17	8 49.4	+ 41 .545	+0 .10	20	. . .	. . .	. .	0	64.248	. . .	3	Clouds
24	8 59.6	+ 19 .400	+0 .05	40	9 2.5	−78.861	−0.06	7	64.241	178.64	2	
25	9 0.1	+ 21 .331	+0 .05	26	. . .	. . .	. .	0	. . .	. . .	3	Clouds
27	8 36.2	+ 26 .920	+0 .05	40	8 36.8	−77.440	−0.05	6	64.253	178.51	3	
28	9 45.0	+ 29 .171	+0 .05	40	9 45.7	−77.864	−0.05	6	. . .	. . .	2	
29	8 56.3	+ 29 .871	+0 .05	40	8 57.2	−78.653	−0.05	7	. . .	. . .	3	
June 2	8 52.0	+ 13 .554	+0 .04	40	8 52.1	−82.167	−0.09	6	64.243	178.54	3	
5	8 39.6	− 8 .055	0 .00	10	8 47.5	−48.556	−0.17	5	64.244	178.16	2	Clouds interrupt. *Iapetus* [faint
8	. . .	. . .	. .	0	9 2.3	−55.009	−0.05	5	64.244	178.16	3	Chronograph failed
9	9 40.9	− 19 .415	−0 .01	12	9 44.4	−57.532	−0.10	6	. . .	. . .	2	*Iapetus* barely visible.
11	8 51.9	− 16 .150	−0 .01	40	8 55.9	−61.138	0.00	5	64.251	178.16	3	
12	9 3.5	− 13 .709	−0 .01	40	9 3.7	−62.392	0.00	5	64.236	. . .	3	
16	8 47.2	− 14 .360	0 .00	40	8 52.8	−63.002	0.00	5	64.238	. . .	3	*Iapetus* very faint
21	9 9.1	− 41 .055	+0 .02	40	9 7.5	+66.910	+0.06	5	64.234	. . .	3	*Iapetus* faint
22	9 13.3	− 44 .355	+0 .04	40	9 13.9	+68.933	+0.07	5	. . .	. . .	3	
23	9 1.2	− 45 .802	+0 .02	40	9 1.7	+71.322	+0.09	5	64.243	. . .	3	
28	9 6.0	− 29 .074	+0 .06	40	9 6.9	+79.882	+0.15	6	64.252	178.16	3	
29	9 2.6	− 24 .297	+0 .07	40	9 9.0	+79.966	+0.15	5	. . .	178.36	4	*Iapetus* faint
1895												
Mar. 22	12 56.6	+ 11 .471	+0 .02	40	12 50.8	+61.401	+0.09	5	64.185	356.30	3	
23	12 42.4	+ 14 .979	+0 .01	40	12 38.5	+60.859	+0.18	5	. . .	. . .	2	
Apr. 3	13 39.8	+ 34 .179	+0 .15	40	13 35.2	−84.504	−0.02	5	64.190	(356.21)	3	Corr. to α +0″.32
4	13 23.4	+ 29 .190	+0 .14	20	13 47.0	−84.693	−0.03	5	. . .	356.28	2	Clouds
5	11 54.8	+ 25 .195	+0 .17	40	11 56.3	−84.142	−0.02	5	. . .	. . .	2	Weather thick
11	11 45.0	+ 29 .116	+0 .13	40	11 45.8	−78.344	−0.02	5	64.185	356.28	3	Wind; telescope shaken
15	11 41.8	+ 31 .414	+0 .12	40	11 45.5	−84.667	−0.07	5	64.171	. . .	3	
17	12 14.1	+ 20 .565	+0 .08	40	12 14.5	−87.634	−0.14	5	64.183	356.30	4	
18	12 18.3	+ 13 .105	+0 .06	40	12 21.2	−87.905	−0.14	5	64.193 } 64.204 }	. . .	4	
19	12 38.2	p247°.72	+0°.012	4	12 46.7	s39.942	+0.42	4	64.200	356.30	2	Mic. increased 4 revolutions
23	12 0.7	p328 .14	0 .00	6	12 0.5	s36.665	+0.10	5	64.192	. . .	2	
May 4	11 27.0	− 28ˢ.170	−0″.09	40	11 27.0	+60.319	+0.06	5	64.222	355.25	5	
9	10 47.6	− 48 .440	−0 .13	40	10 50.4	+73.853	+0.07	5	64.194	. . .	2	Cloudy. *Iapetus* faint
10	10 22.4	− 47 .034	−0 .13	40	10 23.5	+77.013	+0.15	5	64.189 } 64.195 }	. . .	3	
18	9 31.0	− 20 .747	−0 .03	40	9 31.5	+78.405	+0.19	5	64.191	355.27	2	Wind shakes telescope
20	9 12.7	− 25 .678	−0 .04	16	9 30.6	+76.900	+0.17	1	64.190	. . .	2	Clouds interrupt obs.
22	8 55.9	− 30 .819	−0 .06	40	8 54.6	+77.937	+0.13	5	64.190	. . .	2	Thick. *Iapetus* faint
23	9 52.0	− 31 .841	−0 .07	40	9 51.6	+79.392	+0.12	5	64.190	. . .	3	Thick. *Iapetus* faint
28	10 0.2	p 51°.16	+0°.153	4	10 10.5	s39.048	+0.12	5	64.173	. . .	3	
29	8 51.5	p257 .34	+0 .350	4	9 7.0	s43.932	+0.13	5	64.220	. . .	2	
June 1	9 15.2	p328 .33	+0 .080	4	9 26.8	s35.801	+0.10	5	64.173	. . .	3	
3	10 6.5	+ 20ˢ.129	+0″.04	40	10 7.2	+57.769	+0.02	5	64.197	. . .	3	
6	9 5.5	+ 14 .752	+0 .03	40	9 4.3	+63.684	+0.03	5	64.194	355.30	3	
7	8 38.5	p355°.51	+0°.077	4	8 49.0	s83.426	+0.05	5	64.200	. . .	3	
17	9 34.0	+ 47ˢ.072	+0″.12	20	9 54.9	−73.422	+0.50	5	64.201	. . .	4	
1896												
Apr. 26	11 59.8	+ 20 .204	+0 .04	40	11 59.3	+29.103	+0.14	5	179.41	25.009	3	W. & S. micrometer
May 4	11 22.4	+ 45 .271	+0 .21	40	11 22.3	−82.487	+0.03	5	356.62	64.184	2	d
6	10 56.8	+ 35 .552	+0 .22	40	10 56.8	−86.030	0.00	5	356.61	64.185	2	b
9	10 33.2	+ 22 .677	+0 .19	40	10 34.3	−84.021	−0.02	5	356.65	64.181	2	d

Date	W.M.T.	$\alpha_1 - \alpha_2$	Total Corr.	No.	W.M.T.	$\delta_1 - \delta_2$ Mic. Read.	Total Corr.	No.	Mic. Zero	Parallel	Image		
1896	h m				h m	r	″						
May 10	10 19.6	+ 21ˢ.049	+0″.18	40	10 19.3	−82.182	−0.02	5	. . .	64.182	2	d	
11	10 34.8	+ 21 .071	+0 .16	40	10 37.0	−80.395	−0.04	5	356.62	64.190	3	d	
14	11 4.0	+ 28 .820	+0 .13	40	11 3.7	−78.200	−0.01	5	. . .	64.191	4	d	
16	10 20.3	+ 33 .625	+0 .14	20	11 31.8	−81.002	+0.10	5	356.62	64.200 64.188	3	b d	Clouds
27	10 16.9	− 17 .532	−0 .05	40	10 17.2	−54.129	−0.09	5	356.64	64.208	2	d	Thick. *Iapetus* faint
29	10 40.1	p345°.51	−0°.007	6	10 40.1	s41.372	+0.07	5	[356.74]	64.193	2	b	
30	9 22.2	p347 .51	+0 .001	6	9 23.2	s44.939	+0.06	5	356.74	64.193	2	b	
June 1	10 11.2	p344 .87	−0 .006	6	10 11.2	s72.865	+0.03	5	356.62	64.200	3	c	
2	9 31.2	p341 .57	−0 .004	6	9 31.2	s78.287	+0.06	5	. . .	64.180	3	d	
5	9 5.6	− 20ˢ.373	−0″.03	46	8 50.5	−58.509	+0.07	5	356.58	64.186	4	d	
10	9 40.7	− 46 .700	−0 .09	40	9 38.9	+70.235	+0.19	5	356.63	. . .	1		Seeing very poor
11	9 1.8	− 47 .592	−0 .09	40	9 1.7	+74.042	+0.18	5	. . .	64.177 64.196	2	d b	Seeing very poor
12	9 29.4	− 46 .424	−0 .07	40	9 26.2	+77.773	+0.18	5	[356.70]	64.196	2	b	*Iapetus* very faint
15	8 46.9	− 33 .542	−0 .01	40	8 47.7	+84.151	+0.31	5	356.71	64.192 64.187	.	p	
17	9 1.9	− 23 .646	+0 .03	40	9 0.3	+83.417	+0.33	5	. . .	. . .	3		
19	9 42.4	− 19 .255	+0 .05	40	9 53.6	+79.870	+0.37	4	. . .	. . .	2		Clouds. *Iapetus* faint
20	8 43.8	− 19 .700	+0 .02	40	8 13.5	+78.282	+0.20	5	356.71	64.219 64.198	4	d p	Light clouds. *Iapetus* faint
26	9 31.6	− 29 .817	0 .00	40	9 31.6	+81.436	+0.15	5	. . .	64.176 64.190	2	d p	
29	9 30.6	p218°.61	+0°.014	6	9 31.0	s97.417	+0.13	7	356.71	64.191 64.201	4	d p	
30	8 50.7	p233 .88	+0 .100	6	8 58.0	s90.820	+0.13	5	. . .	64.197 64.202	4	d	
July 1	8 52.2	p 78 .63	+0 .030	6	8 53.2	s85.994	+0.16	5	. . .	. . .	4		

In the reduction of the observations, the adopted value of one revolution of the micrometer-screw was 9″.936. This value is the result of unpublished observations of Prof. Hall, together with a rediscussion of some of the earlier values. It rests entirely upon measures of differences of declination between well known groups of stars, and is closely confirmed by the values derived from measures of the focal length of the objective and the linear value of one revolution of the screw. Two such values, one given in Appendix I, *Washington Observations*, 1877, the other from unpublished measures of Prof. Harkness, made shortly after the remounting of the telescope at this site, give 9″.939 and 9″.93756 respectively.

As the coincidence of the micrometer-wire with the fixed wire remained practically constant the mean for each series was used in deriving the measured distances and differences of declination. The mean position of the equator-point of the position-circle was also used for the same reason, for such times as it remained unaltered by adjustment or otherwise.

When necessary, the observed $\Delta\delta$ was corrected to reduce it to the time of the $\Delta\alpha$, and to both were applied the corrections for differential refraction and for the motion of the planet in the interval $\Delta\alpha$. When position-angle and distance were observed, the former was corrected to reduce it to the time of the distance measure, and both corrected for refraction. The observed quantities were reduced to rectangular coördinates by the formula

$$x_1 - x_2 = (\alpha_1 - \alpha_2)\cos\frac{\delta_1+\delta_2}{2} - (x_1+x_2)(y_1-y_2)\frac{\tan\delta\sin 1''}{2}$$

$$y_1 - y_2 = \delta_1 - \delta_2 \qquad\qquad + (x_1+x_2)(x_1-x_2)\frac{\tan\delta\sin 1''}{2}$$

The small quantities represented by the last term in these equations are included in the "total correction" given in the table of observations. In these computations I have followed generally the methods and formulas of H. Struve (Supplement I, *aux Observations de Pulkowa*, 1888). The computed quantities, corresponding to those derived from observation, were obtained by the well known formulas of Bessel (*Astr. Nachr.* Vol. 9, No. 193), using the following assumed elements of the satellites for the epoch 1895.0, G.M.T.:

Titan.		*Iapetus.*	
	° ′ ″		° ′ ″
E_1	86 1 58.7	E_2	60 40 3.4
P_1	277 40 4.2 + 31″.3 t	P_2	353 36 30.7 + 1″.438 t
n_1	168 19 27.8 + 35″.537 t	n_2	141 55 11.4 − 2″.1 t
i_1	27 33 52.9 − 0″.253 t	i_2	18 30 57.5 − 0 .18 t
e_1	0.02922326	e_2	0.027795
Δ_1	176″.60	Δ_2	514″.636
λ_1	22°.5769962	λ_2	4°.53794773

For *Titan* the mean longitude was taken from Bessel's tables, to which was added the constant 12′ 48″.7, for the

difference of longitude between Paris and Greenwich, and an assumed correction of $+4' \; 2''.2$ to BESSEL's mean longitudes. The longitude of the node on the ecliptic, n_1, and the inclination, i_1, were taken directly from the same tables. The eccentricity and the corresponding equation of the center and radius vector were taken from the tables of Prof. A. HALL, JR. (*Trans. Ast. Obsy. of Yale College*, Vol. I, Part II).

For *Iapetus*, all the data, except Δ_2, were taken without correction from Prof. A. HALL's tables of *Iapetus*. (*Washington Observations*, 1882, Appendix I).

From these elements, and the apparent obliquity of the ecliptic for the respective epochs of each of the three series, the auxiliary quantities N, I and u were computed for each satellite, and the rectangular coordinates x_1, y_1 and x_2, y_2, using the formulas of BESSEL.

The comparison of the computed with the observed quantities, is given in the column C − O. The residuals v_x and v_y in the same table are the results of substitution in the equations of condition of the values derived from the fourth solution given on page 87. The values adopted from the fifth solution differ so little from these, that the work of substitution was omitted.

COMPUTED — OBSERVED PLACES.

Date	Gr. M.T.	x_1	x_2	C $x_1 - x_2$	O $x_1 - x_2$	C − O n	y_1	y_2	C $y_1 - y_2$	O $y_1 - y_2$	C − O n	v_x	v_y
1894	h m	″	″	″	″	″	″	″	″	″	″	″	″
Apr. 23	14 18.6	−104.35	+156.43	−260.78	−262.53	+1.75	+31.23	−153.43	+184.66	+183.53	+1.13	+0.37	−0.43
25	12 58.9	+ 38.87	+ 69.86	− 30.99	− 31.26	+0.27	+39.27	−139.81	+179.08	+177.70	+1.38	* −0.97	+0.06
26	13 54.3	+111.13	+ 22.82	+ 88.31	+ 87.53	+0.78	+34.08	−131.03	+165.11	+164.48	+0.63	−0.24	−0.58
30	14 21.4	+140.55	−157.22	+297.77	+297.33	+0.44	−21.91	− 88.63	+ 66.72	+ 65.20	+1.52	−0.17	−0.19
May 1	13 21.0	+ 82.94	−198.15	+281.09	+280.35	+0.74	−32.59	− 76.91	+ 44.35	+ 42.60	+1.75	−0.12	−0.18
12	14 41.4	+117.52	−522.49	+640.01	+639.50	+0.51	+31.86	+ 69.79	− 37.93	− 39.05	+1.12	+0.10	+0.02
13	13 49.7	+163.48	−533.41	+696.89	+696.15	+0.74	+21.68	+ 81.54	− 59.86	− 61.03	+1.17	+0.44	+0.30
14	13 18.4	+184.03	−541.24	+725.27	+724.10	+1.17	+ 8.00	+ 92.56	− 84.56	− 85.22	+0.66	+0.91	−0.17
15	14 10.7	+173.55	−545.94	+719.49	+719.22	+0.27	− 7.78	+103.77	−111.55	−112.35	+0.80	−0.14	−0.03
17	12 44.0	+ 77.07	−544.80	+621.87	+620.86	+1.01	−34.71	+122.70	−157.41	. . .	. .	−0.10	. .
24	12 53.4	−149.60	−439.97	+290.37	+289.97	+0.40	+18.80	+164.22	−145.42	−145.30	−0.12	−1.11	−0.23
25	12 53.8	− 93.02	−413.65	+320.63	+318.84	+1.79	+29.25	+166.34	. . .	. . .	. .	+0.08	. .
27	12 29.8	+ 49.56	−354.57	+404.13	+402.38	+1.75	+35.88	+167.60	−131.72	−131.18	−0.54	−0.20	+0.42
28	13 38.0	+117.66	−320.13	+437.79	+436.03	+1.76	+30.46	+166.70	−136.24	−135.39	−0.85	−0.11	+0.44
29	12 49.6	+161.76	−286.61	+448.37	+446.50	+1.87	+20.60	+164.92	−144.32	−143.24	−1.08	+0.13	+0.43
June 2	12 46.9	+ 69.61	−134.60	+204.21	+202.60	+1.61	−30.79	+148.32	−179.11	−178.18	−0.93	−0.70	+0.55
5	12 32.2	−131.60	− 13.30	−118.30	−120.40	+2.10	−30.05	+127.05	−157.10	−156.04	−1.06	−0.25	+0.27
8	12 54.6	−178.60	+108.49	−287.09	. . .	. .	+ 6.18	+ 99.18	− 93.00	− 91.80	−1.20	. . .	+0.25
9	13 33.1	−141.33	+148.66	−289.99	−290.20	+0.21	+19.17	+ 88.47	− 69.30	− 66.78	−2.52	−1.05	−0.66
11	12 43.8	− 17.44	+222.42	−239.86	−241.41	+1.45	+34.29	+ 66.63	− 32.37	− 30.86	−1.51	−0.33	+0.44
12	12 55.3	+ 54.64	+258.16	−203.52	−204.93	+1.41	+34.53	+ 54.86	− 20.33	− 18.40	−1.93	−0.40	+0.21
16	12 38.5	+163.57	+381.04	−217.47	−218.68	+1.21	− 8.01	+ 6.17	− 14.18	− 12.33	−1.85	−0.07	+0.17
21	12 59.7	−132.35	+480.12	−612.47	−613.61	+1.14	−28.65	− 54.41	+ 25.76	+ 26.56	−0.80	−0.53	+0.02
22	13 3.8	−170.58	+491.16	−661.74	−662.90	+1.16	−18.84	− 65.68	+ 46.84	+ 46.67	+0.17	−0.25	+0.78
23	12 51.6	−184.47	+498.92	−683.39	−684.56	+1.17	− 6.53	− 76.39	+ 69.86	+ 70.43	−0.57	−0.10	−0.05
28	12 55.7	+ 56.95	+489.74	−432.79	−434.45	+1.66	+33.60	−121.43	+155.03	+155.53	−0.50	+0.30	+0.07
29	12 52.3	+116.79	+478.28	−361.49	−363.06	+1.57	+28.20	−128.24	+156.44	+156.37	+0.07	+0.39	+0.60
1895 Mar. 22	16 50.4	−192.12	−361.17	+169.05	+168.89	+0.16	+ 5.61	− 24.27	+ 29.88	+ 27.88	+2.00	+0.20	−0.20
23	16 36.4	−171.19	−392.43	+221.24	+220.55	+0.69	+26.17	− 8.96	+ 35.13	+ 33.29	+1.84	+0.75	−0.22
Apr. 3	17 34.6	− 40.33	−545.04	+504.71	+503.81	+0.90	−55.66	+144.56	−200.22	−201.86	+1.64	−0.24	+0.71
4	17 18.2	−107.69	−539.19	+431.50	+430.32	+1.18	−48.21	+154.55	−202.76	−203.74	+0.98	+0.03	+0.15
5	15 49.6	−157.83	−530.66	+372.83	+371.50	+1.33	−34.39	+163.20	−197.59	−198.26	+0.67	+0.27	−0.03
11	15 40.1	+ 19.04	−412.34	+431.38	+429.48	+1.90	+54.87	+196.26	−141.39	−140.65	−0.74	+0.37	+0.28
15	15 38.9	+183.23	−281.96	+465.19	+463.50	+1.69	−10.30	+195.17	−205.47	−203.52	−1.95	+0.28	−0.40
17	16 9.3	+100.13	−204.89	+305.02	+303.47	+1.55	−47.04	+187.49	−234.53	−233.09	−1.44	−0.34	−0.01
18	16 13.5	+ 30.25	−164.60	+194.85	+193.41	+1.44	−55.29	+181.96	−237.25	−235.37	−1.48	−0.69	−0.18
19	16 33.5	− 45.15	−122.90	+ 77.75	+ 76.81	+0.94	−55.08	+175.25	−230.33	−228.80	−1.53	* −1.00	−0.25
23	15 55.9	−193.86	+ 45.58	−239.44	−241.23	+1.79	+ 8.26	+138.97	−130.71	−129.13	−1.58	* +0.26	−0.19
May 4	15 22.1	+ 24.98	+439.29	−414.31	−416.20	+1.89	−54.10	− 14.69	− 39.41	− 38.42	−0.99	+0.14	+0.04
9	14 42.2	−192.34	+521.94	−714.28	−715.90	+1.62	+ 8.76	− 87.12	+ 95.88	+ 96.07	−0.19	+0.36	−0.01
10	14 17.5	−165.31	+528.37	−693.68	−695.18	+1.50	+27.65	−100.03	+127.68	+127.55	+0.13	+0.19	+0.29
18	13 24.5	+148.53	+453.49	−304.96	−306.76	+1.80	−30.69	−173.25	+142.56	+141.42	+1.14	+0.37	+0.63
20	13 7.2	+ 24.14	+401.78	−377.64	−379.71	+2.07	−52.41	−180.50	+128.09	+126.45	+1.64	+0.10	+0.45

Date	Gr. M.T.	x_1	x_2	C x_1-x_2	O x_1-x_2	C − O n	y_1	y_2	C y_1-y_2	O y_1-y_2	C − O n	v_x	v_y
1895	h m	″	″	″	″	″	″	″	″	″	″	″	″
May 22	12 50.0	−114.66	+339.04	−453.70	−455.82	+2.12	−43.99	−182.74	+138.75	+136.71	+2.04	+0.31	+0.56
23	13 46.2	−165.78	+302.49	−468.27	−470.95	+2.68	−29.08	−181.89	+152.81	+151.16	+1.65	+1.14	+0.03
28	14 4.4	− 38.31	+100.39	−138.70	−139.67	+0.97	+50.04	−159.00	+209.03	+207.28	+1.75	* −0.15	+0.23
29	13 0.8	+ 32.80	+ 58.98	− 26.18	− 26.58	+0.40	+50.18	−151.33	+201.51	+199.66	+1.85	* −0.63	+0.47
June 1	13 20.3	+179.83	− 72.19	+252.02	+251.55	+0.47	+ 8.22	−121.41	+129.63	+127.75	+1.88	* +0.19	+0.48
3	13 59.6	+140.80	−157.88	+298.68	+297.87	+0.81	−31.36	− 97.08	+ 65.72	+ 63.83	+1.89	+0.40	+0.06
6	12 58.5	− 54.36	−273.53	+219.17	+218.33	+0.84	−49.95	− 57.25	+ 7.30	+ 5.07	+2.23	+0.11	−0.04
7	12 42.4	−117.50	−308.73	+191.23	+191.16	+0.07	−41.79	− 43.17	+ 1.38	− 0.96	+2.34	* −0.48	+0.03
17	13 25.9	+176.77	−520.40	+697.17	+696.93	+0.24	+ 6.54	+ 96.91	− 90.37	− 91.22	+0.85	+0.18	+0.13
1896													
Apr. 26	15 54.3	−131.34	−424.81	+293.47	+293.69	−0.22	+51.05	+ 5.94	+ 45.11	+ 43.39	+1.62	−0.03	−0.11
May 4	15 16.9	+112.60	−546.45	+659.05	+658.70	+0.35	−55.51	+125.65	−181.16	−181.75	+0.59	−0.06	−0.29
6	14 51.3	− 25.59	−544.30	+518.71	+517.46	+1.25	−66.62	+119.39	−216.01	−216.98	+0.97	+0.34	+0.20
9	14 27.8	−185.10	−516.66	+331.56	+330.21	+1.35	−17.99	+178.17	−196.16	−197.04	+0.88	+0.62	+0.56
10	14 14.4	−193.61	−501.23	+307.62	+306.53	+1.09	+ 7.06	+185.67	−178.61	−178.77	+0.16	+0.35	+0.04
11	14 29.3	−174.03	−482.45	+308.42	+306.87	+1.55	+31.48	+192.16	−160.68	−161.03	+0.35	+0.70	+0.19
14	14 58.5	+ 12.25	−409.35	+421.60	+419.76	+1.84	+64.17	+204.42	−140.25	−139.19	−1.06	+0.55	+0.14
16	14 14.6	+142.07	−349.48	+491.55	+489.80	+1.75	+37.92	+206.41	−168.49	−166.93	−1.56	+0.76	+0.05
27	14 14.6	−169.67	+ 83.46	−253.13	−255.53	+2.40	+32.55	+134.14	−101.59	−100.09	−1.50	+1.33	−0.27
29	14 10.9	− 56.00	+165.15	−221.15	−222.46	+1.31	+61.77	+108.13	− 46.36	− 44.18	−2.18	* −0.08	−0.50
30	13 17.0	+ 14.43	+202.12	−187.69	−188.87	+1.18	+62.72	+ 94.95	− 32.21	− 30.67	−1.54	* −0.14	+0.29
June 1	14 4.9	+141.99	+277.17	−132.18	−133.03	+0.85	+35.35	+ 65.06	− 29.71	− 27.66	−2.05	* −0.05	−0.24
2	13 24.8	+176.70	+310.51	−133.81	−135.30	+1.49	+12.16	+ 50.16	− 38.00	− 36.35	−1.65	* +0.72	0.00
5	12 59.1	+104.24	+399.85	−295.61	−297.03	+1.42	−54.35	+ 3.14	− 57.49	− 56.40	−1.09	+0.08	−0.35
10	13 33.7	−184.59	+494.96	−679.55	−681.21	+1.66	−13.80	− 74.35	+ 60.55	+ 60.24	+0.33	+0.44	+0.23
11	12 54.7	−188.51	+504.07	−692.58	−694.27	+1.69	+ 9.72	− 88.23	+ 97.95	+ 98.05	−0.10	+0.14	−0.28
12	13 22.2	−164.99	+510.13	−675.12	−677.24	+2.12	+32.80	−102.12	+134.92	+135.13	−0.21	+0.89	−0.40
15	12 39.5	+ 19.03	+507.20	−488.17	−489.35	+1.18	+60.90	−137.99	+198.89	+198.61	+0.28	−0.27	+0.31
17	12 54.2	+144.34	+487.85	−343.51	−345.01	+1.50	+33.79	−157.54	+191.33	+191.34	−0.01	+0.38	−0.07
19	13 34.5	+175.64	+454.66	−279.02	−280.98	+1.96	−15.33	−172.73	+157.40	+156.15	+1.25	+0.86	+0.64
20	12 35.9	+148.97	+434.48	−285.51	−287.45	+1.94	−37.00	−178.22	+141.22	+140.20	+1.02	+0.62	+0.11
26	13 23.0	−182.19	+251.80	−433.99	−435.12	+1.13	−11.84	−185.68	+173.84	+171.50	+2.34	+0.03	+0.18
29	13 22.1	−110.30	+135.56	−245.86	−245.82	−0.04	+50.11	−172.08	+222.22	+220.71	+1.51	* −0.96	−0.22
30	12 49.0	− 47.04	+ 95.76	−142.80	−143.08	+0.28	+59.05	−165.35	+224.10	+222.70	+1.70	* −0.60	+0.14
July 1	12 44.1	+ 24.44	+ 54.65	− 30.21	− 30.33	+0.12	+58.96	−157.10	+216.36	+214.65	+1.71	* −0.63	+0.31

The coefficients of the equations of condition were computed for each satellite from the formulas of Bessel, just as if each satellite had been referred to the planet's center, except that those of *Iapetus* were reversed in sign. The form of each equation is

$$a_1\,\delta E_1 + b_1 e_1\,\delta P_1 + c_1\,\delta e_1 + d_1\,\delta J_1 + e_1 \sin J_1\,\delta N_1 + f_1\,\delta l_1 - a_2\,\delta E_2 - b_2 e_2\,\delta P_2 - c_2\,\delta e_2 - d_2\,\delta J_2 - e_2 \sin J_2\,\delta N_2 - f_2\,\delta l_2 + n = 0.$$

In forming the coefficients, in order to reduce their magnitude, each one has been divided by its corresponding Δ, thus expressing all the corrections to elements in seconds of arc. The computations have been checked in two ways, first, by checking the numerical work, and second, by plotting the coefficients on ruled paper with the longitude of the satellite as abscissas. They may thus be affected by systematic error, but the computation of several dates has been carefully made in duplicate to guard against this.

In the formation of the normal equations, all but two of the equations of condition have been given equal weight, those of 1894 June 9, and 1895 May 20, which were given half weight. Following strictly the estimates of the observing books, nearly all the observations when *Iapetus* was at or near eastern elongation should have been given smaller weights; this, however, would have made the resulting elements depend too much on the observations at western elongation and at the two conjunctions. In forming the squares and products of the coefficients, the latter were taken to the nearest third decimal of their natural numbers, and the operations performed by means of Crelle's tables.

The normal equations on following page are for each separate year, and for the three years combined, giving the equations of declination-differences double weight. Those for the three years combined, in which the equations of right-ascension and declination are given equal weight, are easily formed from those for the separate years.

Normal Equations.

1894. Epoch May 26th, $14^h.54$ G.M.T.

a_1	b_1	c_1	d_1	e_1	f_1	$-a_2$	b_2	c_2	d_2	e_2	f_2	n
16.1830	−5.5659	−10.8948	+1.1697	−5.1464	+1.7293	−0.0606	−10.2365	+2.0909	+0.3062	−1.2215	+0.4044	+7″.4698
	9.5948	+13.2182	−2.0819	+1.7406	+0.9005	+1.0650	+13.2179	−8.0964	+0.1447	−0.3449	−0.7447	−13.1738
		68.0455	−7.3217	+1.8561	−1.6649	+3.4948	+59.5093	−22.3500	−4.7429	+0.2610	+2.5418	−48.7010
			13.2258	−0.5187	+2.8378	+2.4339	−6.3557	+2.5167	+5.8225	+1.2649	−0.5437	+3.7117
				13.2855	+0.7276	−1.9862	+2.0955	−1.6790	−0.6435	+5.8030	−3.2207	+4.9831
					14.1758	−0.5514	−0.5988	−2.3220	−0.3063	+1.1575	−1.4144	−0.1482
						14.6131	+3.4762	−0.3171	−0.2777	−1.7009	+4.7665	−13.8277
							57.2974	−22.9350	−4.6814	−0.1861	+1.7319	−45.0909
								16.4416	+0.0828	+0.9571	+0.7653	+16.9108
									15.1506	+2.8282	+1.1661	+2.9874
										13.9413	+0.3668	+17.6594
											13.3731	+0.5052
												76.0694

1895. Epoch May 5th, $10^h.1$ G.M.T.

15.7002	+6.5185	+11.3828	+0.0133	−6.3293	+2.6965	+1.8635	+8.9261	−6.1366	−1.7497	+0.4612	+1.1354	−8″.9905
	17.8217	+22.3656	+3.6704	−3.0823	−1.3276	−2.8424	+21.8231	−18.3130	−4.5247	+0.7415	−0.6093	−12.4671
		60.0699	+4.8332	−1.6375	+2.6712	−3.5054	+50.2634	−30.4811	−4.8480	−0.8628	+0.6622	−47.9556
			14.7568	+0.2439	+3.3574	−0.8158	+3.1148	−3.6156	+0.9151	−0.0366	+0.3162	−7.4185
				14.0875	−0.9155	−0.3177	−1.3617	+3.5026	−0.0514	−0.3853	−0.8679	−4.2418
					14.2927	+0.3226	+1.4363	+2.3776	+0.6220	+1.3956	+2.3530	−4.2009
						16.1695	−4.2019	+5.0492	−1.1736	−0.5847	+5.7647	−8.1247
							48.3400	−29.9068	−4.1417	−0.1351	+0.3316	−41.0479
								28.9375	+3.8368	−0.9282	+1.4362	+14.7546
									13.9544	+3.4485	+1.2731	+4.7603
										13.1558	+1.6713	+24.4339
											14.5271	+4.6331
												108.3336

1896. Epoch June 1st, $10^h.0$ G.M.T.

14.9180	−7.6436	−12.0430	−1.6228	−7.1965	+3.7879	−1.3304	−10.1351	+9.5777	−2.3048	−0.1010	−0.6601	+9″.6400
	24.6082	+23.0890	+1.5168	+0.0200	+1.4522	+4.0665	+19.7160	−26.8743	+1.2117	−1.3110	+1.8302	−23.3382
		50.7679	+3.2215	+3.5772	−3.7587	+2.0136	+35.9289	−30.7137	+2.6319	+2.2028	−0.7090	−40.1133
			16.5112	+0.3163	+3.8866	−0.1183	+3.5642	−4.4411	−2.8615	−0.7026	+1.2403	−5.1733
				14.7549	−3.2694	+1.1090	+2.3886	−0.4010	+0.8518	−0.8697	+2.7054	−9.0275
					12.6515	+0.4970	−1.5200	−2.1684	−0.3390	−1.3447	+1.4530	−1.5646
						12.8857	+0.8544	−5.9030	−1.1871	−0.2297	+6.3357	−14.5578
							30.6852	−25.0580	+1.9132	+1.2302	−0.0710	−32.4817
								38.0020	−3.8305	+1.5507	−1.9785	+31.0467
									16.9329	+2.9432	+0.4156	−1.8431
										10.6684	+0.4114	+15.3614
											16.7634	−0.1063
												92.1775

1894-5-6 ($\Delta\delta$ double weight). Epoch May 21st, $19^h.7$ G.M.T.

50.0910	−6.1334	−12.0911	−0.4055	−29.9533	+9.1399	+0.5375	−11.8461	+4.9759	−3.7244	−1.5587	+0.8163	+11″.2673
	64.5308	+52.6252	+3.8631	−3.7227	+3.0890	+2.6731	+55.5625	−68.2917	−3.8178	−2.5027	−0.3148	−42.8140
		182.9469	+0.1555	+5.8137	−4.0792	+1.6645	+145.9279	−76.0740	−6.7755	+2.5700	+2.2939	−139.6559
			47.8021	+0.1746	+20.4319	+1.8255	+0.6257	−6.6531	+4.1010	+0.2370	+2.0997	−11.7110
				82.9844	−5.6768	−2.2634	+4.4112	+3.8623	−0.1249	+9.1004	−2.6260	−17.0933
					81.0036	+0.4638	+0.1363	−5.2039	+0.7247	+2.4529	+4.5897	−12.2923
						48.2091	−0.1561	−1.8294	−2.5616	−13.2083	+23.3563	−54.6002
							138.5930	−78.9406	−6.7445	+1.7255	+1.7884	−119.1209
								103.5857	+0.7355	+3.8943	+0.5278	+56.0697
									51.0173	+15.7275	+15.0503	+19.8519
										73.4761	+3.4181	+120.2134
											84.6658	+13.2389
												411.2085

Although the number of equations of condition forming the normals for each series is too small to give a good solution with twelve unknown quantities, yet, for the purpose of indicating the presence of systematic errors, I have solved each series separately. The results of these solutions, for the three years combined giving equal weights to the equations of $\Delta\alpha$ and $\Delta\delta$, and finally for the three years combined giving the latter equations double weight, are given below in tabular form. The relatively larger probable error of a single observation given by the last two solutions will doubtless be reduced to agree more closely with that resulting from the separate series by the use of a more nearly correct value for P_1, P_2, n_2 and i_2, which would result from the use of more accurate values of the secular changes in these elements.

Correction to Elements Derived from Solution of Normal Equations.

	1894			1895			1896			1894–5–6 I			1894–5–6 II		
	Corr.	p.e.	Wt.	Corr.	p.e.	Wt.	Corr.	p.e.	Wt.	Corr.	p.e.	Wt.	Corr.	p.e.	Wt.
	″	″		″	″		″	″		″	″		″	″	
δE_1	+0.1700	0.0755	9.3	+0.1880	0.0695	11.0	+0.5200	0.0839	9.5	+0.2004	0.0472	35.5	+0.1906	0.0457	36.7
$e_1\,\delta P_1$	+0.4351	.1135	4.1	−0.0412	.1121	4.2	+0.0651	.1078	4.7	+0.2462	.0759	16.8	+0.2002	.0642	18.6
δe_1	+0.4190	.0958	5.8	+0.2882	.0862	7.2	+0.2469	.0831	7.9	+0.4279	.0650	22.9	+0.4140	.0523	28.0
δJ_1	−0.1390	.0780	8.7	+0.3300	.0682	11.5	+0.1944	.0652	12.8	+0.1355	.0486	40.9	+0.1397	.0429	41.7
$\sin I_1\,\delta N_1$	+0.2466	.0805	8.1	+0.2980	.0710	10.6	+0.5136	.0736	10.0	+0.4377	.0537	33.4	+0.4048	.0349	62.8
δI_1	+0.2668	.0677	11.8	+0.1805	.0706	10.7	+0.1718	.0769	8.4	+0.2298	.0511	37.1	+0.2327	.0332	69.6
δE_2	+0.7473	.0687	11.0	+0.8078	.0663	12.2	+1.5015	.0786	8.8	+0.9347	.0516	36.4	+0.9328	.0446	38.4
$e_2\,\delta P_2$	+0.5102	.1203	3.7	+0.9890	.1140	4.1	+1.2186	.1163	4.0	+0.6252	.0803	15.0	+0.6671	.0670	17.0
δe_2	+0.6398	.1085	4.5	+0.5926	.0968	5.7	+0.4643	.0939	6.1	+0.4634	.0680	20.9	+0.4771	.0548	25.4
δJ_2	+0.4532	.0716	10.4	+0.4387	.0702	10.8	+0.5293	.0634	13.4	+0.4629	.0484	41.3	+0.4529	.0424	42.7
$\sin I_2\,\delta N_2$	−1.3889	.0737	9.7	−1.8031	.0684	11.4	−1.7413	.0768	9.2	−1.6580	.0534	33.9	−1.6468	.0349	63.3
δI_2	−0.3872	0.0717	10.3	−0.6000	0.0677	11.7	−0.5614	0.0657	12.6	−0.4574	0.0509	37.0	−0.4606	0.0338	67.1

	1894	1895	1896	1894–5–6 I	1894–5–6 II
$[nn]\,12$	5″.8219	5″.6638	6″.0008	29″.5684	35″.8268
$[rr]$	5.4456	5.6709	5.8508	29.9392	–
r_1	±0.2301	±0.2306	±0.2331	±0.3130	±0.2761

The results of the last column are adopted as definitive, and their application to the assumed elements give as the corrected elements, referred to the epoch 1895 May 22.0 G.M.T., the following: —

Titan.

	°	′	′	′
E	52	1.81	± 0.896	(+1.25)
P	280	5.7	± 42.6	(+6.38)
N	125	3.33	± 6.035	
I	6	28.52	± 0.301	
n	168	24.80		(−1.75)
i	27	42.66		(−0.23)
e	0.031568		± 0.000294	(+0.00006)
Δ	176″.740		± 0″.043	

Iapetus.

	°	′	′	′
E	345	16.60	± 0.301	(+ 4.54)
P	356	15.07	± 16.13	(−43.60)
N	52	9.21	± 0.952	
I	14	10.06	± 0.227	
n	142	5.09		(− 6.49)
i	18	20.00		(+ 1.70)
e	0.0287226		± 0.000107	(−0.00016)
Δ	515″.089		± 0″.042	

The quantities in parentheses are the reductions for the periodic disturbances caused by the Sun. Struve, in the work previously cited, has derived the most probable elements of *Iapetus* and *Titan*, and their perturbations of long period caused by the Sun, the ellipticity of *Saturn* and his rings, and the other satellites. A comparison of these elements, reduced to the epoch 1895.34, with those derived from my observations is given below. The elements of *Titan*, derived by A. Hall, Jr., are also thus given, as a confirmation of the still greater increase necessary in the value of ΔP_1 adopted by Bessel.

Iapetus.

	Struve	Brown
	° ′	° ′
E_2	345 19.92	345 20.14
P_2	355 16.8	355 31.5
n_2	141 58.00	141 58.60
i_2	18 23.0	18 21.70
e_2	0.02850	0.02871
Δ_2	514″.589 ± 0″.040	515″.089 ± 0″.042

Titan.

	Struve	Brown	A. Hall, Jr.
	° ′	° ′	° ′
E_1	51 57.80	52 3.06	51 58.9
P_1	278 47.5	280 12.1	280 7.5
n_1	168 21.02	168 23.05	168 20.28
i_1	27 39.74	27 42.43	27 40.77
e_1	0.029053	0.031629	0.029112
Δ_1	176″.651 ± 0″.024	176″.740 ± 0″.043	176″.570 ± 0″.0243

The close agreement of the elements of *Iapetus*, with the exception of important quantity Δ_2, is all that could be desired. In the case of *Titan*, however, the differences in the values of E_1, n_1, i_1 and e_1, are much greater than would

be expected from their respective probable errors. I think they are due to systematic errors in the observations of right-ascension differences, caused by the great variation in the brightness of *Iapetus* between his eastern and western elongations. As the principal purpose of this communication is to give an abstract of a more complete discussion to appear shortly in the regular publications of the observatory, it will suffice to give the resulting mass of *Saturn*, with a brief comparison of it with the different values previously obtained.

Neglecting the influence of systematic errors on the value of Δ_1 and Δ_2 and adopting for λ_1, STRUVE's value 22°.5770116, and for λ_2, 4°.537797, there results, from the values of Δ_1 and Δ_2 given in the corrected elements, the following values of the mass of *Saturn*: —

From *Titan*, $\frac{1}{m} = 3490.4 \pm 2.55$

From *Iapetus*, $\frac{1}{m} = 3491.8 \pm 0.85$

Combining these two results according to their weights we get $\frac{1}{m} = 3491.7 \pm 0.81$

This value, it will be seen, lies between that of Prof. HALL on the one side and those of BESSEL, H. STRUVE and A. HALL, JR., on the other. STRUVE corrects BESSEL's value for an error in the scale-value of the heliometer and for an error in the assumed mean distance of *Saturn*, deriving a final value of the reciprocal of the mass of 3502.5. HALL's values corrected to his finally adopted value of the micrometer-screw would be 3493.8 for *Iapetus* and 3482.7 for *Titan*, from the measurements of position-angle and distance. STRUVE further points out that these values, as well as those resulting from the observations of $\Delta\alpha$ and $\Delta\delta$, may require a still further positive correction of about two units on account of the partial use of BOUVARD's tables of *Saturn*. From data furnished me by Prof. NEWCOMB, I find that the value of Δ_2 will be reduced by 0″.047 for the results of right-ascension and declination, and by 0″.024 for the results of position-angle and distance. This would increase the mass, derived from all of HALL's observations of *Iapetus* and *Titan*, by 0.7 of a unit in the value of $\frac{1}{m}$ Leaving this small correction out of consideration, we have the following determination of the reciprocal of *Saturn's* mass:

From Titan.

Bessel,	1831.2	Heliometer	3502.5 ± 0.77
A. Hall,	1876.7	$\Delta\alpha$ and $\Delta\delta$	3496.3 ± 1.84
A. Hall,	1878.7	*s* and *p*	3482.7 ± 1.49
A. Hall, jr.	1886.3	Heliometer	3500.5 ± 1.44
H. Struve,	1885.7	$\Delta\alpha$ and $\Delta\delta$	3495.7 ± 1.43
Brown,	1896.3	$\Delta\alpha$ and $\Delta\delta$	3490.4 ± 2.55

From Iapetus.

A. Hall,	1880.2	*s* and *p*	3493.8 ± 0.97
A. Hall,	1876.7	$\Delta\alpha$ and $\Delta\delta$	3481.2 ± 0.65
H. Struve,	1885.7	$\Delta\alpha$ and $\Delta\delta$	3500.2 ± 0.82
Brown	1896.3	$\Delta\alpha$ and $\Delta\delta$	3491.8 ± 0.85

The value derived by Prof. GEO. W. HILL from the action of *Saturn* on *Jupiter* is 3502.2 ± 0.53. [*Astronomical Papers of the American Ephemeris*, Vol. VII, Part I, p. 17].

There is little probability that the value last given will be much changed by future investigations of the same kind, and hence it is probable that the values resulting from direct observations of the satellites are affected more or less by systematic errors inherent in the method by which they are obtained.

So far as concerns the observations of the present series there is evidence of systematic error which would make the resulting mean distances too great, and the corresponding mass also too great. All the quantities (C—O) derived from differences of right-ascension are positive, while there is also a preponderance of positive residuals in this coördinate resulting from the substitution of the derived values in the equations of condition. This may be explained on the supposition that transits of *Iapetus* were always observed too late, and that this error was greater when *Iapetus* was at or near eastern elongation, in which portion of its orbit it was often almost invisible. Such a variation of the personal equation would be in accord with general experience where transits are recorded by means of the chronograph. A difference of $0^s.04$ in the personal equation for *Iapetus* would be sufficient to cause a change of ten units in the value of $\frac{1}{m}$

A series of measurements, by micrometer and by transits, of the difference of right-ascension between two stars of the estimated magnitudes of $8^M.5$ and $11^M.0$, indicated that the faint star was observed $0^s.017$ too late. If, owing to atmospheric conditions, the faint star should be near the limit of visibility, this error might amount to two or even three times this quantity. The effect of such an error might be eliminated by introducing into the $\Delta\alpha$ equations of condition one or two terms, the coefficients of which would be functions of the brightness of *Iapetus*, but I think such expedients for bringing out desired results are dangerous. The observations were carefully made and have been reduced and discussed by the usual methods, and must stand for the present for what they are worth, whether or not they agree with others supposed to be nearer the truth. If the observations of *Rhea–Iapetus* now in progress, in which the variation of relative brightness is much less, should confirm the supposition of such systematic error in the *Titan–Iapetus* observations, I should rather reluctantly adopt the above expedient.

U.S. Naval Observatory, Washington, D.C., 1898 *Aug.* 11.

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DETERMINATION OF THE ABERRATION-CONSTANT FROM RIGHT-ASCENSIONS,

BY S. C. CHANDLER.

Among the resources furnished by practical astronomy for finding the amount of the aberration is the use of the observed right-ascensions of circumpolar stars. This method is subject to conspicuous and well recognized defects. Nevertheless the desirability of utilizing for this difficult problem as many modes of determination as possible, in the hope that the systematic errors of each may be in some sort eliminated or rendered less prejudicial to the result of their final combination, has led to several investigations of this constant based on right-ascensions. Probably few astronomers regard such determinations as entitled to so much confidence as those made by other methods. To be sure, the trustworthiness of some of these other methods was recently gravely threatened, when the phenomenon of the variation of latitude was first recognized. But this difficulty has now happily almost entirely disappeared, since the rapid advance in our knowledge of the laws which regulate this phenomenon has permitted the elimination of its effects from the more important past determinations of the aberration, and arrangements of observation have been contrived by which future determinations can be protected from it. On the contrary, the sources of uncertainty which attend the use of right-ascensions for the purpose in question remain as obscure and menacing as ever. These arise principally from the undeterminable effects of systematic diurnal variations in the instrumental azimuths, or from the questions of various sorts connected with variations of personal equation due to the effects of direction of motion, or of differences in the aspect of stars observed at different times of the day, with varying illumination of the background, and the like. Neither of these sources of uncertainty is imaginary. Both of them may operate implicitly, and approximately at least, as functions of the same element, the longitude of the sun, which regulates the amount of the aberration, and thus factitiously affect the determination of the latter.

Among existing series of right-ascension observations which have been employed to determine the constant of aberration, those made with the Pulkowa Transit appear to me to be the only ones which, by reason of the control afforded by the system of *mires*, can be regarded as protected from liability to the uncertainties of the first, or instrumental, sort above spoken of, sufficiently to be profitably used in the investigation of the aberration. But the results from them are open to vitiation by the influences of the second sort, namely, variations in personal error of transits due to the causes specified.

It is the object of this paper to present the results of an investigation of these observations, undertaken for the purpose of eliminating, from the values of the aberration which they furnish, the systematic errors in question, so far as possible. It appeared to me that this might be done, partially at least, by separating the observations into two portions — namely, those from January to June, and those from July to December — during which *Polaris* is observed under materially different conditions, at the two culminations, in regard to the aspect of the star as affected by illumination of the sky, or otherwise. During the first half of the year, when the star is thrown forward of its true place in right-ascension by aberration, the upper culmination occurs in daylight or bright twilight, the maximum aberration coinciding with noon culmination; while during the latter half of the year, when the star is thrown backward by aberration, upper culmination occurs at night or in faint twilight, generally speaking, the minimum aberration coinciding with midnight culmination. It would seem proper and reasonable therefore, in view of these opposite conditions, to treat the two portions, in the solution for finding the aberration-constant, as distinct series so far as the unknown quantity indicating the correction to the assumed right-ascension is concerned. At least this ought to afford an approximate elimination from the aberration-correction of the effect of the error with which we are concerned.

The following table contains the material which I have collected, and arranged in convenient shape for use, from the classical memoirs of LINDHAGEN and NYRÉN. Under the head of SCHWEIZER are given the results, as I have condensed them, of the 396 equations on pp. 254–261 of the Pulkowa "*Recueil*," assembled in semi-monthly means, the observations being given equal weight. The values of n are taken in the sense C–O. These observations were reduced by LINDHAGEN with the aberration 20″.453, PETERS's nutation and BESSEL's right-ascension and proper motion. I have added the constant $+0^s.73$ to conveniently reduce the size of the residuals. The relative weights, p, are assigned proportional to the number of observations (one-fifth). Under the head of WAGNER I have given the corresponding semi-monthly means from pp. 41–42 of NYRÉN's memoir, changing the sign of n, and with a relative scale of weight one-fifth of his weights.

SCHWEIZER.			WAGNER					
			Eye-and-Ear			Chronographic		
t	n	p	t	n	p	t	n	p
Jan. 3	$+0^s.360$	1	Jan. 8	$-0^s.250$	2	Jan. 12	$-0^s.010$	1
31	+ .210	1	24	+ .360	2	27	+ .490	1
Feb. 7	– .103	1	Feb. 3	+ .116	1	Feb. 5	– .421	2
20	– .390	1	18	– .547	1	21	– .270	1
Mar. 9	+ .444	2	Mar. 10	– .221	1	Mar. 8	+ .260	1
22	+ .087	7	26	– .171	2	23	– .337	3
Apr. 8	+ .086	7	Apr. 8	+ .068	9	Apr. 9	+ .226	10
22	+ .189	8	22	– .036	6	21	+ .302	7
May 7	– .041	6	May 9	– .127	8	May 11	+ .067	7
25	+ .008	7	22	– .224	7	21	– .016	4
June 9	– .169	6	June 7	– .406	8	June 7	– .193	9
22	– .015	4	23	– .128	6	22	– .040	8
July 9	– .016	3	July 7	+ .039	6	July 7	– .018	7
23	+ .072	2	23	– .135	4	22	– .031	5
Aug. 8	– .016	6	Aug. 8	– .020	1	Aug. 8	– .090	1
23	+ .162	3	25	+ .167	1	25	+ .134	1
Sept. 13	– .412	3	Sept. 11	+ .055	1	Sept. 10	+ .161	1
21	– .199	5	26	– .433	3	26	– .186	4
Oct. 9	– .357	4	Oct. 8	– .166	6	Oct. 7	+ .006	6
23	– .042	3	24	– .292	2	26	– .256	4
Nov. 2	– .357	1	Nov. 10	– .309	1	Nov. 9	– .263	4
17	+ .983	1	24	– .200	2	22	+ .161	4
Dec. 5	– .363	1	Dec. 7	– .545	2	Dec. 8	– .442	4
19	+0.220	1	25	–0.388	2	25	+0.242	2

If $\Delta\alpha$ and u be the corrections to the adopted right-ascension and aberration-constant, respectively, and π the parallax, then with the assumption of a circular orbit for the earth, which will be sufficiently accurate for such small corrections as are involved in the solution, we shall have

$$(1)\quad \begin{cases} 0 = n+\Delta\alpha-\pi(\cos\odot\,\sin\alpha-\sin\odot\,\cos\epsilon\,\cos\alpha)\,\dfrac{\sec\delta}{15} \\ \qquad -u\,(\sin\odot\,\sin\alpha+\cos\odot\,\cos\epsilon\,\cos\alpha)\,\dfrac{\sec\delta}{15} \end{cases}$$

$$(2)\quad \text{Put}\quad p = \cos\alpha\,\cos\epsilon\,\frac{\sec\delta}{15}\quad,\quad q = \sin\alpha\,\frac{\sec\delta}{15}$$

$$(3)\quad X = -\Delta\alpha\quad,\quad Y = qu-p\pi\quad,\quad Z = pu+q\pi$$

and we get as the form of conditional equation

$$(4)\quad X + Y\sin\odot + Z\cos\odot = n$$

With the values of Y and Z found from the solution of these we get

$$(5)\quad u = \frac{qY+pZ}{p^2+q^2}\quad,\quad \pi = \frac{qZ-pY}{p^2+q^2}$$

The normal equations, formed for the three series as described, are as follows:

SCHWEIZER: 396 obs., 1842–44.

January–June.

$$\begin{array}{rrrl} 51.\ X_1 & +24.18\,Y & +33.37\,Z & = +2^s.43 \\ +24.18\,X_1 & +23.82\,Y & +10.69\,Z & = -0.56 \\ +33.37\,X_1 & +10.69\,Y & +27.18\,Z & = +2.84 \end{array}$$

July–December.

$$\begin{array}{rrrl} 33.\ X_2 & +\ 4.96\,Y & -24.93\,Z & = -2.86 \\ +\ 4.96\,X_2 & +11.98\,Y & -\ 3.03\,Z & = +0.03 \\ -24.93\,X_2 & -\ 3.03\,Y & +21.02\,Z & = +3.10 \end{array}$$

WAGNER, Eye-and-Ear; 439 obs., 1861–72.

January–June.

$$\begin{array}{rrrl} 53.\ X_1 & +27.50\,Y & +29.60\,Z & = -5.99 \\ +27.50\,X_1 & +30.78\,Y & +11.27\,Z & = -6.89 \\ +29.60\,X_1 & +11.27\,Y & +22.26\,Z & = -2.00 \end{array}$$

July–December.

$$\begin{array}{rrrl} 31.\ X_2 & +\ 1.47\,Y & -18.67\,Z & = -5.56 \\ +\ 1.47\,X_2 & +16.25\,Y & -\ 0.11\,Z & = +2.89 \\ -18.67\,X_2 & -\ 0.11\,Y & +14.75\,Z & = +3.42 \end{array}$$

WAGNER, Chronographic; 429 obs., 1861–72.

January–June.

$$\begin{aligned} 54.\ X_1 &+28.99\,Y +30.92\,Z = +1\overset{s}{.}34 \\ +28.99\,X_1 &+29.66\,Y +10.87\,Z = +0.38 \\ +30.92\,X_1 &+10.87\,Y +24.34\,Z = +2.43 \end{aligned}$$

July–December.

$$\begin{aligned} 43.\ X_2 &- 3.60\,Y -25.57\,Z = -3.50 \\ -3.60\,X_2 &+23.54\,Y + 3.06\,Z = +1.36 \\ -25.57\,X_2 &+ 3.06\,Y +19.46\,Z = +2.32 \end{aligned}$$

Eliminating X_1 and X_2, and summing the elimination-equations for each of the three series, we get

SCHWEIZER.

$$\begin{aligned} +23.59\,Y - 4.41\,Z &= -1\overset{s}{.}25 \\ -4.41\,Y + 7.53\,Z &= +2.19 \end{aligned}$$

WAGNER, Eye-and-Ear.

$$\begin{aligned} +32.06\,Y - 3.32\,Z &= -0.63 \\ -3.32\,Y + 9.24\,Z &= +1.41 \end{aligned}$$

WAGNER, Chronographic.

$$\begin{aligned} +37.33\,Y - 4.81\,Z &= +0.73 \\ -4.81\,Y +10.89\,Z &= +1.90 \end{aligned}$$

Solving for Y and Z, and determining X_1 and X_2 by substitution in the original normal equations, we find

	X_1	X_2	Y	Z
	s	s	″	″
SCHWEIZER,	−0.144	+0.134	+0.001	+0.292
WAGNER (E. & E.),	−0.196	−0.088	−0.004	+0.152
WAGNER (Chron.),	−0.110	+0.038	+0.044	+0.194

Then by means of eq. (5) we find, with the values, $p = +2.215$, $q = +0.682$ (Schweizer); $p = +2.371$, $q = +0.811$ (Wagner); computed by eq. (2):

(6)	u			Aberration	Parallax
	″	″		″	″
SCHWEIZER,	+0.120	+20.453	=	20.573	+0.032
WAGNER (E. & E.),	+0.061	+20.445	=	20.506	+0.022
WAGNER (Chron.),	+0.084	+20.445	=	20.529	+0.009

These values of the aberration are in every case a notable increase of those obtained by LINDHAGEN and NYRÉN from the same observations, which are

	Aberration	Parallax	Δa
	″	″	
LINDHAGEN : SCHWEIZER,	20.498	+0.026	+0.738
NYRÉN : WAGNER (E.&E.),	20.478	+0.016	+0.155
NYRÉN : WAGNER (Chron.),	20.489	+0.005	+0.027

The parallaxes, however, as will be seen, are practically unaltered. To show that the differences in the aberration are in no way attributable to errors or differences in the methods of solution, I append the values which we get from the above normal equations, ignoring the differences between X_1 and X_2; *i.e.*, summing the two sets for the two halves of the year, and solving:

	Aberration	Parallax	Δa
	″	″	
SCHWEIZER,	20.500	+0.032	+0.735
WAGNER (E.&E.),	20.477	+0.019	+0.143
WAGNER (Chron.),	20.490	+0.006	+0.034

These are practically identical with LINDHAGEN's and NYRÉN's values, immediately preceding. This verifies both solutions.

It is interesting to compare the values of the right-ascension of *Polaris*, herein deduced separately from the observations in the first and second halves of the year. By eq. (3) we have $X_2 - X_1 = \Delta a_1 - \Delta a_2$; whence

	$\Delta a_1 - \Delta a_2$
	s
SCHWEIZER,	+0.278
WAGNER (E. & E.),	+0.108
WAGNER (Chron.),	+0.148

This quantity, positive in every case, represents the excess of the right-ascension given by the observations of January–June over that given by those of July–December: or the excess of the right-ascension when the star, at upper culmination, is observed in daylight over that when it is observed on a dark sky.

Astronomers will very likely differ as to the significance of the foregoing investigation. My interpretation is that it betrays the real existence of a systematic perturbation in the observations arising from some such cause as I have indicated. And I am inclined to conclude, as respects the aberration, that the values given against (6) should be regarded, under the circumstances, as more legitimately flowing from the series of observations considered than those found by ignoring the effects of systematic personal errors in observing transits under diverse conditions.

In drawing the above inferences I am by no means inclined to assert that the method pursued fully clears the aberration of systematic errors of the kinds described, since even if we admit the probable existence of such errors, as it seems to me we must reasonably do, their nature is at present somewhat obscure. Until this question is cleared up further speculation is idle. I permit myself here only to add a remark on the general nature of the effect on the aberration-constant derived from observations of right-ascensions with an instrument subject to unknown diurnal variations or from observations affected by other undetermined subjective periodical errors dependent on the time of culmination. First, if L be the right-ascension or longitude of the mean sun on the unknown date when such hypothetical error has a maximum effect on the observed right-ascension of the star, the error may be represented under the form

$$\rho \cos (\odot - L) \tag{7}$$

If this term be added to eq. (1), and if we take

$$\eta = \rho \sin L \qquad , \qquad \zeta = \rho \cos L \tag{8}$$

then, instead of (5) the corrections to the assumed aberration and the parallax become

$$u = \frac{q(Y+\eta)+p(Z+\zeta)}{p^2+q^2} \quad , \quad \pi = \frac{q(Z+\zeta)-p(Y+\eta)}{p^2+q^2} \tag{9}$$

Now if the error in question is a function of the time of day, and is a maximum at noon, we can put $L = \alpha$ in (8), and then by means of (2) the equations (9) become, very nearly (since $\cos\epsilon$ is near unity),

$$(10)\qquad u = \frac{qY+pZ}{p^2+q^2} + \rho\,15\cos\delta \quad , \quad \pi = \frac{qZ-pY}{p^2+q^2} + 0$$

Comparing with (5) we see that, under the hypothesis of the existence of any such periodic diurnal error, the aberration-correction found by any process of computation which ignores its existence will be in defect by a constant quantity, while the parallax will be unaffected.

The fact that the discussion in the present paper of three series of observations, introducing merely a distinction between the opposite conditions of the two halves of the year, gives a material positive correction in every instance ($+0''.073$, $+0''.029$, $+0''.039$) to the value of the aberration deduced without making this distinction, while it leaves the parallaxes practically undisturbed, is at least suggestive of the probability of some such cause of systematic error.

NOTES ON VARIABLE STARS, — No. 26,

By HENRY M. PARKHURST.

Local Errors. Hitherto all my photometric observations have been largely affected by the necessary local errors in the standards employed, arising from irregular or unequal atmospheric obscuration. The local error does not affect the time of maximum or minimum, but may need to be considered in comparing the brightness of variables in different years. Until the present year, most of my attempts to correct these errors have necessarily been to obtain local and partial equalization. The elimination of these local errors has now become possible, by means of observations of asteroids. A special standard has been adopted, to conform with the average, derived from nearly a thousand standard stars, by several thousands of photometric observations; and wherever it is practicable this new standard has been made the basis of my observations of variable stars, and of comparison-stars. The constants of twenty asteroids have already been reduced to this standard, and in their wanderings they are continually bringing new regions into conformity with it, and furnishing the means of determining the constants of additional asteroids.

V Librae. My suggested period of 256 days, adopting the epoch of the rejected elements of the Third Catalogue, 24.08566, seems to be confirmed, although the unfavorable weather interfered with observations at the maximum.

Results of Observations.

No.	Star	Phase	Observed Date Julian	Calendar	E	Corr.	W	Mag.	Factors		d	Remarks
				1898								
4315	*R Comae*	Max.	4505.6	Aug. 3	68	− 0.2	9	9.22	0.30	0.17	4	El. *A.J.* 384, 415
4377	*T Virginis*	Max.	4462	June 21	40	−10	4	10.1	0.13	0.13	7	Low in west. Perry later
4407	*R Corvi*	Min.	4464	June 23	35	–	E	–	–	–	–	Midway
4492	*Y Virginis*	Max.	4348	Feb. 27	25	− 2	5	8.7	–	–	–	Close approx. from factors
4573	*RU Virginis*	Min.	4437	May 27	2	+ 4	9	11.59	2.0	2.3	63	Midway; *A.J.* 415
4596	*U Virginis*	Max.	4336	Feb. 15	56	−34	1	–	–	–	–	Subtangent approx.
4665	*RT Virginis*	Max.	4383 :	Apr. 3	–	–	1	–	–	–	–	Highest observation
4816	*V Virginis*	Max.	4475	July 4	56	− 9	9	9.47	0.90	1.27	23	
"	"	Max.	4477	July 6	56	+ 2	3P	–	–	–	–	Highest observation
4826	*R Hydrae*	Max.	4454	June 13	6	− 1	8	4.30	0.20	0.25	15	Another max. much later
4847	*S Virginis*	Max.	4475.5	July 4	45	+18	9	6.38	0.53	0.50	15	
"	"	Max.	4472	July 1	45	+15	4P	6.1	–	–	–	
4885	*Z Centauri*	Max.	3758	July 17	11	–	E	–	–	–	–	1896; *A.J.* 383, 436
4940	*W Hydrae*	Max.	4133	July 27	8	–	E	–	–	–	–	1897
"	"	Max.	4517	Aug. 15	9	–	E	–	–	–	–	1898
4948	*R Canum Ven.*	Max.	4404	Apr. 24	11	−32	6	7.45	–	–	–	Confirms preceding correction
5037	*RR Virginis*	Max.	4427	May 17	32	–	E	–	–	–	–	Clouds prevented further obsn.
5194	*V Bootis*	Min.	4441	May 31	20	− 1	9	10.54	1.67	1.23	41	
5237	*R Bootis*	Min.	4489	July 18	66	+ 4	4	–	–	–	–	
5249	*V Librae*	Max.	4445	June 4	23	− 9	7	10.58	0.83	0.83	30	From elements above
5338	*U Bootis*	Max.	4487	July 16	38	−13	3P	11.3	–	–	–	Highest observation
5405	*RT Librae*	Min.	4526 :	Aug. 24	3	–	E	–	–	–	–	Consistent with period *A.J.* 415
5430	*T Librae*	Max.	4481	July 10	31	+ 2	8	10.98	0.54	0.67	18	
5501	*S Serpentis*	Max.	4487	July 16	70	+35	3P	8.6	–	–	–	Highest observation
5511	*RS Librae*	Max.	4491	July 20	15	−14	3	9.0	0.83	–	–	Two observations and factor

Individual Observations.

Including Observations by Arthur C. Perry.

4315 *R Comae.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4500.5	July 29	9.13$_4$
4502.5	31	9.24$_4$
4504.5	Aug. 2	9.29$_5$
4506.5	4	9.16$_5$
4507.5	5	9.45$_5$

4377 *T Virginis.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4347.6	Feb. 26	10.8]
4396.6	Apr. 16	12.9]
4419.6	May 9	12.9:
4419.6	9	12.0:P
4450.6	June 9	11.0:
4450.6	9	12.0P
4458.6	17	10.9
4461.6	20	10.10$_2$
4462.6	21	10.2P
4465.6	24	10.78$_2$
4477.6	July 6	10.1P

4407 *R Corvi.*

(Continued from 384.)

Julian	Calendar 1898	Mag.
4386.6	Apr. 6	10.9:
4396.6	16	11.9
4398.5	18	11.83$_2$
4419.6	May 9	12.5
4428.6	18	13.63$_2$
4450.6	June 9	11.6]
4458.6	17	13.2]

4492 *Y Virginis.*

(Cont. from 415. Comp. Stars 415.)

Julian	Calendar 1898	Mag.
4347.6	Feb. 26	8.74$_2$
4352.6	Mar. 3	9.03$_2$
4363.6	14	9.56$_2$

4573 *RU Virginis.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4347.6	Feb. 26	10.4
4366.5	Mar. 17	10.8
4396.6	Apr. 16	11.1
4419.6	May 9	11.6
4431.6	21	11.7
4450.6	June 9	11.6
4462.6	21	11.3
4476.6	July 5	11.61$_2$
4486.6	15	10.9

4596 *U Virginis.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4347.6	Feb. 26	8.6
4352.6	Mar. 3	8.59$_2$
4363.6	14	8.72$_2$
4383.5	Apr. 3	9.22$_2$
4388.5	8	9.39$_2$

4665 *RT Virginis.*

Julian	Calendar 1898	Mag.
4383.5	Apr. 3	8.46$_2$
4427.6	May 17	9.4P
4450.6	June 9	9.4P
4464.6	23	9.4P
4477.6	July 6	9.6P
4487.6	16	9.4P

4816 *V Virginis.*

(Continued from 384.)

Julian	Calendar 1898	Mag.
4423.6	May 13	12.0]
4450.6	June 9	10.4
4450.6	9	10.1P
4455.6	14	9.50$_3$
4461.6	20	10.25$_2$
4462.6	21	9.61$_2$
4462.6	21	9.9P
4464.6	23	9.53$_2$
4470.6	29	9.36$_2$
4477.6	July 6	9.68$_2$
4477.6	6	9.8P
4485.6	14	9.35$_2$
4486.6	15	9.46$_2$
4487.6	16	9.8P
4504.6	Aug. 2	10.65
4507.6	5	10.4P

4826 *R Hydrae.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4419.6	May 9	7.9
4419.6	9	7.5P
4427.6	17	7.2P
4440.6	30	6.94$_2$
4446.6	June 5	6.09$_2$
4446.6	5	5.8P
4450.6	9	5.19$_2$
4456.6	15	3.61$_2$

4826 *R Hydrae.* — Cont.

Julian	Calendar 1898	Mag.
4458.6	June 17	5.15$_2$
4458.6	17	5.3P
4461.6	20	4.99$_2$
4462.6	21	5.18$_2$
4464.6	23	5.3P
4478.6	July 7	4.6P
4487.6	16	4.4P

4847 *S Virginis.*

Cont. from 415. Comp. Stars 384

Julian	Calendar 1898	Mag.
4424.6	May 14	10.01$_2$:
4427.6	17	8.8P
4440.6	30	8.11$_2$
4446.6	June 5	8.38$_2$
4446.6	5	8.2P
4449.6	8	6.99$_2$
4455.6	14	6.68$_2$
4458.6	17	6.9P
4461.6	20	6.71$_2$
4462.6	21	6.7P
4464.6	23	6.80$_2$
4470.6	29	6.52$_2$
4473.6	July 2	6.32$_2$
4477.6	6	6.37$_2$
4477.6	6	6.3P
4480.6	9	6.41$_2$
4484.6	13	6.79$_2$
4485.6	14	6.72$_2$
4487.6	16	6.6P
4507.6	Aug. 5	7.2P

4885 *Z Centauri.*

Julian	Calendar 1896	Mag.
3695.7	May 15 to	
3740.6	June 29	14]
	5 dates	

4940 *W Hydrae.*

Julian	Calendar	Mag.
	1897	
4067.6	May 22	8.1P
4074.7	29	8.2P
4098.6	June 22	8.0P
	1898	
4462.6	June 21	8]P
4478.6	July 7	9.7:P

4948 *R Canum Venat.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4387.6	Apr. 7	8.24$_2$
4392.5	12	7.81$_2$
4398.5	18	7.14$_2$
4410.5	30	7.90$_2$
4419.5	May 9	7.60$_2$
4431.6	21	8.27$_2$

5037 *RR Virginis.*

Continued from 356.

Julian	Calendar 1898	Mag.
4396.6	Apr. 16	12.3]
4419.6	May 9	12.6]
4423.6	13	12.2:
4450.6	June 9	12.0]

5194 *V Bootis.*

Cont. from 415. Comp. Stars 333

Julian	Calendar 1898	Mag.
4387.6	Apr. 7	9.47$_2$
4398.5	18	9.38$_2$
4410.5	30	10.42$_2$
4419.5	May 9	10.46$_2$
4431.6	21	10.42$_2$
4441.6	31	10.56$_2$
4452.6	June 11	10.50$_2$
4462.6	21	10.78$_2$
4471.6	30	9.38$_2$
4472.6	July 1	9.74$_2$

5237 *R Bootis.*

(Cont. from 415. Comp. Stars 333

Julian	Calendar 1898	Mag.
4478.6	July 7	12.7
4487.6	16	13.0
4506.6	Aug. 4	12.0

5249 *U Librae.*

(Cont. from 415. Comp. Stars 388

Julian	Calendar 1898	Mag.
4423.6	May 13	11.0
4440.6	30	10.76$_2$
4446.6	June 5	10.62$_2$
4455.6	14	10.55$_2$
4461.6	20	11.04$_2$
4462.6	21	10.83$_2$

5338 *U Bootis.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4450.6	June 9	12.0P
4462.6	21	11.9P
4477.6	July 6	11.4P
4487.6	16	11.3P
4507.6	Aug. 5	11.6P

5405 *RT Librae.*

(Continued from 415.)

Julian	Calendar 1898	Mag.
4419.6	May 9 to	
4515.5	Aug. 13	11.0]
	4 dates	

5430 *T Librae.*

(Continued from 388.)

Julian	Calendar 1898	Mag.
4419.6	May 9	12.2]
4450.6	June 9	12.0]
4450.6	9	10.2]P
4458.6	17	12.4
4461.6	20	12.00$_2$
4465.6	24	11.89$_2$
4477.6	July 6	10.82$_2$
4478.6	7	11.07$_2$
4481.6	10	10.90$_2$
4486.6	15	11.09$_2$
4489.6	18	11.18$_2$

5501 *S Serpentis.*

(Cont. from 415. Comp. Stars 388

Julian	Calendar 1898	Mag.
4427.6	May 17	11.5P
4446.6	June 5	10.6P
4458.6	17	10.2P
4464.6	23	9.2P
4477.6	July 6	8.6P
4487.6	16	8.6P
4507.6	Aug. 5	8.7P

5511 *RS Librae.*

Cont. from 415. Comp. Stars 388

Julian	Calendar 1898	Mag.
4419.7	May 9	12.0
4450.6	June 9	10.5
4458.6	17	10.3
4477.6	July 6	9.28$_2$
4481.6	10	9.2P
4486.6	15	9.06$_2$

Comparison-Stars. — 1893–1898

4596 *U Virginis.*

Star	DM.	Mag.	n
I	+6°2673	7.00	7
1*I*	+7°2580	6.82	6
1*K*	+5°2682	6.74	9
R	+6°2672	8.96	14
1*T*	+6°2666	9.49	10
3*T*	+6°2676	9.16	10
X	+6°2670	9.56	10
Y	+5°2685	9.70	1
Z	+6°2665	10.26	4
a	3*p* *V*	10.52	12
b	8*f* *V*	10.59	6
d	8*sf* *V*	10.98	7

4816 *V Virginis.*

Star	DM.	Mag.	n
E	−2°3695	6.85	24
I	−2°3684	7.09	17
M	−2°3698	8.81	10
N	−2°3703	8.56	15
Q	−2°3701	8.42	5
S	−2°3697	9.12	17
T	−2°3689	9.62	23
U	−2°3702	9.08	5
X	−2°3688	10.74	2
1*X*	−2°3690	10.65	7
Y	−2°3687	11.24	2
Z	−2°3691	11.03	3

4826 *R Hydrae.*

Star	DM.	Mag.	n
I°	−22°3554	3.47	4
P°	−17°3813	4.60	5
Q°	−22°3515	5.29	14
S°	−19°3653	5.14	11
U°	−19°3651	5.29	9
C	−22°3645	5.99	9
D	−22°3630	6.76	9
G	−22°3604	7.16	12
J	−22°3589	8.16	5
L	−22°3605	9.75	3
Q	−22°3592	8.73	5
T	−22°3600	9.21	5

4847 *S Virginis.*

Star	DM.	Mag.	n
C	−5°3706	6.27	19
D	−6°3839	7.17	29
1*D*	−5°3702	7.38	19
J	−7°3633	7.93	11
1*J*	−6°3843	8.12	7
K	−7°3635	8.71	10
N	−6°3834	8.83	35
1*Q*	−6°3827	9.28	8
S	−5°3715	9.39	3
1*S*	−6°3832	9.52	24
U	−6°3836	9.90	15
1*U*	−6°3840	9.65	22

OBSERVATIONS OF COMET c 1898 (CODDINGTON),

MADE AT THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA,

BY WILLIAM J. HUSSEY.

1898 Mt. Hamilton M.T.	✱	No. Comp.	☄ − ✱		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
	h m s			m s	′ ″	h m s	° ′ ″		
June 11 9 13 7	1	10 , 10	+0 30.79	+0 38.7	16 24 56.15	−25 14 20.6	n9.375	0.872
10 13 7	1	9 , 10	+0 22.27	−0 53.7	16 24 47.63	−25 15 53.0	n9.042	0.888
15 8 43 30	2	10 , 10	−0 38.54	+2 23.6	16 11 23.71	−27 45 12.7	n9.387	0.880
16 10 24 56	3	10 , 10	−0 7.18	−2 6.3	16 7 39.08	−28 25 14.5	n7.128	0.903
17 11 28 42	5	8 , 8	−0 8.44	−2 50.2	16 3 58.76	−29 3 56.9	9.212	0.905
12 8 35	5	8 , 8	−0 11.39	−3 53.0	16 3 52.81	−29 4 59.7	9.396	0.884
18 9 50 51	6	8 , 8	−0 4.05	−5 2.0	16 0 41.46	−29 38 10.8	n8.668	0.907
10 14 41	7	8 , 8	−0 43.70	+2 40.5	16 0 38.08	−29 38 51.8	7.978	0.907
19 9 33 33	8	8 , 8	+0 5.92	+7 29.2	15 57 10.86	−30 14 4.7	n8.846	0.908
20 10 40 57	10	8 , 8	−0 6.72	+1 4.6	15 53 26.49	−30 51 44.5	9.030	0.907
22 10 43 8	11	8 , 8	−0 17.96	+1 37.3	15 46 16.93	−32 2 9.2	9.164	0.908
23 8 49 58	13	8 , 8	−0 21.88	−3 51.4	15 42 59.31	−32 33 50.1	n9.020	0.913
24 9 17 31	14	8 , 8	+0 37.62	+1 38.5	15 39 20.91	−33 8 18.2	n8.307	0.918
26 8 52 21	15	10 , 10	−0 44.43	+4 37.3	15 32 18.06	−34 13 37.3	n8.662	0.930
July 13 8 56 7	16	8 , 8	+0 34.45	−1 42.5	14 37 36.22	−41 49 16.1	9.450	0.910
14 8 40 26	18	8 , 8	−0 9.30	−2 36.1	14 34 54.29	−42 10 25.5	9.411	0.915
18 8 41 54	20	8 , 8	+0 5.69	−7 40.3	14 24 41.14	−43 31 44.8	9.525	0.901
19 8 42 23	21	8	. . .	+1 21.4	. . . .	−43 51 19.0	. .	0.897
19 8 52 56	22	8 , 8	+0 33.88	−4 10.4	14 22 15.91	−43 51 21.0	9.577	0.890

Mean Places for 1898.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 24 21.16	+4.20	−25 14 47.2	−12.1	Tucker, Lick Obsy. Mer. Circ. 1 obs.
2	16 11 58.01	+4.24	−27 47 22.8	−13.5	$\frac{1}{3}$(γ 6848 + Cord. Z. 748 + Cord. Gen. Catal. 22077)
3	16 7 42.01	+4.25	−28 22 54.2	−14.0	13ᴹ ± connected with ✱4
4	16 11 58.33	+4.27	−28 21 34.8	−13.6	$\frac{1}{2}$(Gould, G.C. 22078 + Stone, Radc. Catal. 4222)
5	16 4 2.94	+4.26	−29 00 52.2	−14.5	Gould, Gen. Catal. 21900
6	16 0 41.24	+4.27	−29 32 53.9	−14.9	Gould, Zone Catal. 4140
7	16 1 17.50	+4.28	−29 41 17.4	−14.9	Gould, Zone Catal. 4193
8	15 57 0.65	+4.29	−30 21 18.3	−15.6	10ᴹ connected with ✱9
9	15 56 21.48	+4.28	−30 22 50.6	−15.4	Gould, Zone Catal. 3843
10	15 53 28.92	+4.29	−30 52 33.2	−15.9	Gould, Gen. Catal. 21664
11	15 46 30.60	+4.29	−32 3 29.6	−16.9	12½ᴹ connected with ✱12
12	15 47 41.10	+4.30	−32 3 22.5	−16.8	Gould, Zone Catal. 3237
13	15 43 16.91	+4.28	−32 29 41.3	−17.4	Gould, Gen. Catal. 21432
14	15 38 39.02	+4.27	−33 9 38.7	−18.0	Gould, Zone Catal. 2591
15	15 32 58.24	+4.25	−34 17 55.8	−18.8	Gould, Gen. Catal. 21198
16	14 36 57.95	+3.82	−41 47 8.0	−25.6	10ᴹ connected with ✱17
17	14 34 10.98	+3.79	−41 46 22.4	−25.7	Gould, Gen. Catal. 19858
18	14 34 59.80	+3.79	−42 7 23.6	−25.8	11ᴹ connected with ✱19
19	14 35 7.59	+3.80	−42 0 57.3	−25.7	Gould, Zone Catal. 2148
20	14 24 31.79	+3.66	−43 23 37.7	−26.6	Gould, Zone Catal. 1463
21	14 21 14.65	+3.61	−43 52 13.3	−27.1	Gould, Gen. Catal. 19559
22	14 21 38.41	+3.62	−43 46 43.5	−27.1	Gould, Zone Catal. 1283

All $\Delta\alpha$'s and $\Delta\delta$'s were obtained by direct micrometer-comparisons. The observations of June 16, 22, and 23, were made with the 36-inch refractor, and all others with the 12-inch telescope. In reducing the observations of June 11, it has been assumed that the micrometer readings for $\Delta\alpha$ were recorded 10 revolutions too small. The equatorial value of one revolution of the micrometer screw is 14″.059.

Mt. Hamilton, Cal., 1898 *Aug.* 11.

ELEMENTS AND EPHEMERIS OF COMET *c* 1898 (PERRINE),

BY C. D. PERRINE.

The following system of parabolic elements for this comet have been derived from normal places, viz.:

	True α	True δ
	h m s	° ′ ″
1898 June 16.0 Gr. M.T.	3 35 26.05	+58 23 2.5
July 12.0	5 57 56.15	+46 25 51.6
Aug. 7.0	7 41 29.47	+21 9 46.3

The above positions were obtained by comparing observations (Mount Hamilton, June 14, 15, 16, 17; Paris, June 16; Strassburg, June 17 = Mount Hamilton, July 9, 11, 12, 13, 14; Mount Hamilton, August 2, 4, 5, 6, 7, 8) with an ephemeris computed from my elements published in *A.J.* 440. They are free from parallax and aberration.

The mean deviations of the observations on the dates of the normal places were as follows:

O—C	α	δ
	s	″
June 16.0	− 0.42	+ 2.8
July 12.0	+ 3.08	−27.9
Aug. 7.0	+21.76	−6′ 53.4

ELEMENTS.

T = 1898 August 16.19978 Gr. M.T.

$$\left.\begin{aligned} \Omega &= 259^\circ\ 6'\ 12''.2 \\ \omega &= 205\ 36\ 24.0 \\ i &= 70\ \ 1\ 36.7 \end{aligned}\right\} 1898.0$$

$$\log q = 9.796950$$

Residuals for the middle place,

$$\text{O}-\text{C} \qquad \Delta\lambda' \cos\beta' \quad +0''.1$$
$$\Delta\beta' \quad -0.9$$

The constants for the equator of 1898.0 are

$$x = r\,[9.585487]\,\sin(176^\circ\ 12'\ \ 6''.7+v)$$
$$y = r\,[9.999842]\,\sin(\ 89\ 55\ 12.7+v)$$
$$z = r\,[9.965344]\,\sin(180\ 33\ 54.0+v)$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1898	True α	True δ	log Δ	Br.
	h m s	° ′		
Sept. 2.5	9 34 19	−13 28.0	0.1599	6.79
4.5	44 10	15 50.3		
6.5	9 54 8	18 7.0	0.1671	5.82
8.5	10 4 14	20 17.9		
10.5	14 26	22 22.7	0.1768	4.91
12.5	24 41	24 21.0		
14.5	35 6	26 12.8	0.1887	4.09
16.5	45 30	27 58.0		
18.5	10 55 55	29 36.6	0.2023	3.39
20.5	11 6 19	31 8.8		
22.5	16 42	32 34.6	0.2171	2.80
24.5	27 2	33 54.2		
26.5	37 18	35 7.8	0.2330	2.32
28.5	47 28	36 15.7		
30.5	11 57 32	37 18.3	0.2493	1.92
Oct. 2.5	12 7 29	38 15.7		
4.5	17 18	39 8.4	0.2660	1.60
6.5	26 57	39 56.6		
8.5	36 27	40 40.7	0.2826	1.34
10.5	45 47	41 20.8		
12.5	12 54 57	41 57.3	0.2991	1.13
14.5	13 3 55	42 30.4		
16.5	12 42	43 0.5	0.3152	0.95
18.5	21 18	43 27.7		
20.5	29 42	43 52.3	0.3309	0.81
22.5	37 54	44 14.6		
24.5	45 55	44 34.6	0.3460	0.70
26.5	13 53 45	44 52.5		
28.5	14 1 23	45 8.6	0.3606	0.60
30.5	8 50	45 23.2		
Nov. 1.5	14 16 6	−45 36.1	0.3745	0.52

Brightness at discovery taken as unity.

Lick Observatory, University of California, 1898 Aug. 24.

OBSERVATIONS OF COMETS,

MADE AT THE STUDENTS' OBSERVATORY, UNIVERSITY OF CALIFORNIA,

BY A. O. LEUSCHNER AND R. T. CRAWFORD.

1898 Berkeley M.T.	*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
			b 1898 (PERRINE).						
	h m s		m s	′ ″	h m s	° ′ ″			
Mar. 22 16 49 12	1	10 , 10	−0 21.61	+21 59.0	21 29 41.68	+19 50 51.2	*n*9.666	0.627	L
29 16 32 40	2	10 , 10	−0 54.55	−12 46.2	21 57 9.79	+26 59 11.3	*n*9.700	0.591	L
Apr. 12 16 0 40	3	14 , 10	+0 17.58	+15 9.8	23 0 3.85	+39 38 59.5	*n*9.779	0.560	L
22 15 57 34	4	10 , 10	+0 41.60	−13 59.5	23 51 9.38	+46 33 16.7	*n*9.830	0.536	C
			c 1898 (CODDINGTON).						
*June 12 12 7 51	5	26 , 16	+0 41.89	+ 5 21.5	16 21 9.20	−25 56 26.3	9.213	0.890	C
16 11 27 32	6	6 , 8	+1 27.30	−17 38.6	16 7 29.35	−28 26 59.0	9.154	0.901	L
17 9 58 2	7	10 , 10	−0 34.16	+ 7 11.4	16 4 11.66	−29 1 16.5	*n*8.670	0.909	L

*Seeing poor; very faint and difficult.

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 30 2.89	+0.40	+19 28 58.1	— 5.9	Auwers, Berlin A.G. Catal. 8802
2	21 58 4.01	+0.33	+27 12 2.9	— 5.4	Graham, Cambridge A.G. Catal. 13128
3	22 59 46.11	+0.16	+39 23 53.1	— 3.4	Tucker, L.O. Meridian Circle.
4	23 50 24.71	+0.07	+46 47 17.6	— 1.4	Deichmüller, Bonn A.G. Catal. 18274
5	16 20 53.10	+4.21	—26 1 35.3	—12.5	Cordoba G.C. 22270
6	16 5 57.81	+4.24	—28 9 6.2	—14.2	½ (Cordoba G.C. 21948 + Cape Catal. 8806)
7	16 4 41.85	+4.27	—29 8 46.4	—14.5	½ (Cordoba G.C. 21913 + Radcliffe$_3$ 4183)

NEW ASTEROID.

Prof. Kreutz communicates the discovery of a new asteroid on Aug. 13, by Witt, Berlin (*Urania*), and the position, *DQ* 11^M 1898 Aug. 14, 12^h 6^m.4 Berlin M.T. $\alpha = 21^h 26^m 32^s.6$, $\delta = -6° 24' 21''$. Daily motion, in α -116^s, northward 1′

A later cable dispatch from Dr. Kreutz, communicated by Mr. Ritchie, states that elements computed from observations on Aug. 14, 23 and 31, show a remarkable orbit, the perihelion distance lying within that of *Mars*, and the mean daily motion in orbit being 2000″.

WOLF'S PERIODIC COMET = *f* 1898.

The object cabled from Europe Sept. 13 as observed by Pechüle ($\alpha = 6^h 10^m 11^s.5$, $\delta = +8° 55' 40''$: daily motion in α $-2^m 0^s$, southward 20′) and as probably a return of Tempel's comet 1866 I, is manifestly Wolf = *f* 1898, which was first observed by Hussey on June 16 (*A.J.* 439).

On receipt of the above cable dispatch, a slight calculation showed that both of the observed coordinates could be exactly reconciled with an orbit having the position and form of that of 1866 I, with a mean daily motion in orbit of 108″.64, and a perihelion passage on 1898 Aug. 16.380 Gr. M.T. But this evidence in favor of identity was completely contradicted by the fact that a body moving in such an orbit would have a geocentric daily motion on Sept. 13 of $-4^m 13^s$ in α, and southward 1° 27′, which is incompatible with the above observed motion. The conclusion of Thraen's ephemeris of Wolf = *f* 1898 (see *A.J.* 442 and *A.N.* 3506) is as follows:

Berlin Midnight	α	δ	log Δ	Br.
	h m s	° ′		
Sept. 21.5	6 24 9	+6 38.5	0.2050	2.6
23.5	27 26	6 2.2	0.2026	
25.5	30 37	5 25.5	0.2001	2.6
27.5	33 41	4 48.4	0.1977	
29.5	36 37	4 11.0	0.1952	
Oct. 1.5	6 39 28	+3 33.2	0.1928	2.7

Ed.

COMET *h* 1898.

[From Mr. Ritchie's *Special Circular, No.* 121].

On September 14, a telegram was received from Harvard College Observatory announcing the discovery of a new comet by Perrine of Lick Observatory, giving two positions. Subsequent particulars were communicated by mail.

1898 Greenw. M.T.	α	δ	Observer
	h m s	° ′ ″	
Sept. 13.0404	9 35 49.3	+31 4 31	Perrine
14.0145	9 41 43.8	30 35 19	Perrine
14.9678	9 47 36.8	+30 4 57	Perrine

From these observations the following elements and ephemeris were computed by Perrine and Aitken of Lick Observatory.

T = 1898 Oct. 20.02 Gr. M.T.

$$\left.\begin{aligned} \omega &= 165° 17' \\ \Omega &= 36\ \ 5 \\ i &= 29\ 12 \end{aligned}\right\} \text{Mean Eq. 1898.0}$$

q = 0.3842

Greenw. Midnight	α	δ	Brightness
	h m s	° ′	
Sept. 18.5	10 9 36	+27 59	1.39
22.5	10 35 12	25 8	
26.5	11 1 20	21 45	
30.5	11 27 44	+17 49	3.03

CONTENTS.

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THE TEN INTEGRALS OF THE PROBLEM OF n BODIES FOR FORCES INVOLVING THE CO-ORDINATES AND THEIR FIRST AND SECOND DIFFERENTIALS,

By KURT LAVES.

Let the rectangular co-ordinates and the masses of the n bodies of a *free* system be designated by x_i, y_i, z_i and m_i respectively, then the fundamental equation of Dynamics is given by

$$\sum_1^n m_i \left\{ \frac{d^2x_i}{dt^2}\,\delta x_i + \frac{d^2y_i}{dt^2}\,\delta y_i + \frac{d^2z_i}{dt^2}\,\delta z_i \right\} = \sum_1^n (X_i\,\delta x_i + Y_i\,\delta y_i + Z_i\,\delta z_i) \tag{a}$$

δx_i, δy_i, δz_i designate virtual displacements which are of the character of independent quantities since the system is assumed to be free. X_i, Y_i, Z_i are the projections of the forces acting upon the system. We shall assume that only those forces exist which arise from the mutual attractions of the n bodies. These forces are called interior forces. Let us make the assumption that these forces depend not only upon the co-ordinates of the different mass-points of the system, but also upon the time and the first and second differentials of the co-ordinates, but with the restriction that they give rise to an *Effective Potential W*. (See Chapter VIII of C. NEUMANN, *Allgemeine Untersuchungen über das Newtonsche Princip der Fernwirkungen* .... Leipzig, 1896). We shall call such forces effective Potential Forces (see also *Vierteljahrsschrift der A.G.* XXXI, 187–191). To obtain the differential equations of motion of the n bodies we transform equation (a) in such a way that the W function can be introduced. Put

$$\delta W = \sum_1^n (X_i\delta x_i + Y_i\delta y_i + Z_i\delta z_i)$$

and consider the integral

$$\int_{t_0}^{t_1} \left[\sum_1^n \left[m_i \left\{ \frac{d^2x_i}{dt^2}\,\delta x_i + \frac{d^2y_i}{dt^2}\,\delta y_i + \frac{d^2z_i}{dt^2}\,\delta z_i \right\} \right] - \delta W \right] dt = 0 \tag{b}$$

Since W depends upon the co-ordinates, the time and the first differentials of the co-ordinates, we obtain

$$\delta W = \sum_1^n \frac{\partial W}{\partial x_i}\,\delta x_i + \sum_1^n \frac{\partial W}{\partial y_i}\,\delta y_i + \sum_1^n \frac{\partial W}{\partial z_i}\,\delta z_i + \sum_1^n \frac{\partial W}{\partial x_i'}\,\delta x_i' + \sum_1^n \frac{\partial W}{\partial y_i'}\,\delta y_i' + \sum_1^n \frac{\partial W}{\partial z_i'}\,\delta z_i'$$

Let the assumption be made that δx_i, δy_i, δz_i disappear for the times t_0 and t_1. The introduction of the definite time integral will enable us to get rid of $\delta x_i'$, $\delta y_i'$, $\delta z_i'$. Indeed we obtain

$$\int_{t_0}^{t_1} \frac{\partial W}{\partial x_i'}\,\delta x_i'\,dt = \int_{t_0}^{t_1} \frac{\partial W}{\partial x_i'}\,d(\delta x_i) = \left.\frac{\partial W}{\partial x_i'}\,\delta x_i\right|_{t_0}^{t_1} - \int_{t_0}^{t_1} \frac{d}{dt}\left(\frac{\partial W}{\partial x_i'}\right)\delta x_i\,dt$$

Introducing this in the equation above and remembering that the expressions of the form $\left.\frac{\partial W}{\partial x_i'}\,\delta x_i\right|_{t_0}^{t_1}$ disappear we obtain

$$\int_{t_0}^{t_1} \left[\sum_1^n \left\{ m_i \frac{d^2x_i}{dt^2} - \frac{\partial W}{\partial x_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial x_i'}\right) \right\} \delta x_i + \sum_1^n \left\{ m_i \frac{d^2y_i}{dt^2} - \frac{\partial W}{\partial y_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial y_i'}\right) \right\} \delta y_i + \sum_1^n \left\{ m_i \frac{d^2z_i}{dt^2} - \frac{\partial W}{\partial z_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial z_i'}\right) \right\} \delta z_i \right] dt = 0 \tag{c}$$

This is HAMILTON'S principle for a free system with rectangular co-ordinates. Since the virtual displacements are independent of each other we obtain the following system of $3n$ differential equations of motion for effective Potential Forces:

$$m_i \frac{d^2x_i}{dt^2} = \frac{\partial W}{\partial x_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial x_i'}\right) = X_i$$

$$\text{(d)} \qquad m_i \frac{d^2y_i}{dt^2} = \frac{\partial W}{\partial y_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial y_i'}\right) = Y_i$$

$$m_i \frac{d^2z_i}{dt^2} = \frac{\partial W}{\partial z_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial z_i'}\right) = Z_i$$

It will be necessary in what follows to use HAMILTON'S equations in general canonical co-ordinates instead of system (d). We can derive them by transforming equation (b) in the following way:

$$\int_{t_0}^{t_1}\left[\sum_1^n m_i\left\{\frac{d^2x_i}{dt^2}\,\delta x_i + \frac{d^2y_i}{dt^2}\,\delta y_i + \frac{d^2z_i}{dt^2}\,\delta z_i\right\}\right]dt = -\int_{t_0}^{t_1}\delta T\,dt$$

where we have put $T = \frac{1}{2}\sum_1^n m_i(x_i'^2 + y_i'^2 + z_i'^2)$ and equation (b) becomes

$$\int_{t_0}^{t_1}\delta\,(T+W)\,dt = 0 \qquad \text{(e)}$$

Introducing instead of the system x_i, y_i, z_i the system of generalized co-ordinates $q_1 \ldots q_k$ into (d) we obtain easily LAGRANGE'S equation of the second kind:

$$\frac{\partial\,(T+W)}{\partial q_a} - \frac{d}{dt}\left(\frac{\partial\,(T+W)}{\partial q_a'}\right) = 0 \qquad \text{(f)}$$

For a free system we have $k = 3n$ of such differential equation of the second order. A restricted system with k degrees of freedom will lead to k equations. To replace this system of differential equations of the second order each, by another system of differential equations of the first order each, we introduce POISSON'S equations in the following generalized form:

$$p_a = \frac{\partial\,(T+W)}{\partial q_a'} \qquad \text{(g)}$$

We have $$\delta\,(T+W) = \sum_1^k{}_a \frac{\partial\,(T+W)}{\partial q_a}\,\delta q_a + \sum_1^k{}_a \frac{\partial\,(T+W)}{\partial q_a'}\,\delta q_a' = \sum_1^k{}_a \frac{\partial\,(T+W)}{\partial q_a}\,\delta q_a + \sum_1^k{}_a\, p_a\,\delta q_a'$$

put $K = \sum_1^k{}_a\, p_a\, q_a' - (T+W)$ and we obtain

$$(\alpha) \qquad \delta K = -\sum_1^k{}_a \frac{\partial\,(T+W)}{\partial q_a}\,\delta q_a + \sum_1^k{}_a\, q_a'\,\delta p_a$$

This expression for δK is obtained by starting from $T+W$ when expressed in function of q_a and q_a'. Regarding K directly as a function of the q_a and p_a we obtain

$$(\beta) \qquad \delta K = \sum_1^k{}_a \frac{\partial K}{\partial q_a}\,\delta q_a + \sum_1^k{}_a \frac{\partial K}{\partial p_a}\,\delta p_a$$

From the comparison of (α) and (β) we find

$$-\frac{\partial\,(T+W)}{\partial q_a} = \frac{\partial K}{\partial q_a} \qquad q_a' = \frac{\partial K}{\partial p_a}$$

In these equations $T+W$ is regarded as expressed in function of q_a and q_a' whereas K is a function of q_a and p_a. To transform equations (f) so as to contain the q_a and p_a as variables we put the last values into (f) and find

$$\text{(h)} \qquad \frac{dp_a}{dt} = -\frac{\partial K}{\partial q_a} \quad \text{and} \quad \frac{dq_a}{dt} = \frac{\partial K}{\partial p_a}$$

(h) constitutes for a free system of n bodies a system of $6n$ differential equations of the first order.

For a free system T will be a homogeneous function of the second degree in q_a' if we assume the same to hold for W we shall have

$$K = \sum \frac{\partial\,(T+W)}{\partial q_a'}\,q_a' - (T+W)$$
$$= 2\,(T+W) - (T+W) = T+W$$

(See P. APPELL, *Mécanique rationnelle*, II, 398.)

Forces of the nature indicated have not been introduced to any extent into the problems of advanced Dynamics. In the "*Vorlesungen über Dynamik*," forces involving velocities are excluded from the general study. But it is obvious that the very valuable introduction of Professor NEUMANN of the Effective Potential W will prove to be of similar importance as LAGRANGE'S introduction of the U function. When we accept the proposition frequently made of introducing one of the electrodynamical laws of WEBER, RIEMANN, or CLAUSIUS into astronomy we are at once thrown upon effective potential forces. Not limiting ourselves to any one of these laws specially, the following question presents itself at once:

What is the most general expression of a W function consistent with the existence of ten integrals in the problem of n bodies?

This problem is solved in the present paper, and the answer is found to be the following:

Regarding ψ to be an arbitrary function of the time and the co-ordinates x_i, y_i, z_i W must be of the form $W = \frac{d\psi}{dt} + V$ where V is an arbitrary function of the

mutual distances and relative velocities of the n bodies and does not contain the time explicitly.

Since the function ψ has the following two properties:

$$(A)\quad \frac{\partial \frac{d\psi}{dt}}{\partial x_i} = \frac{d}{dt}\frac{\partial \psi}{\partial x_i} \qquad \text{and} \qquad (B)\quad \frac{\partial \frac{d\psi}{dt}}{\partial x_i'} = \frac{\partial \psi}{\partial x_i}$$

we see that the function ψ will disappear in the differential equations of motion entirely and the essential part of W is the function V. When we consider the problem of two bodies particularly, we shall see that Jacobi's theory of the last multiplier will enable us always to find the last two integrals. Indeed, it will be shown that since t enters into the differential equations through its differential alone, the time can be found by means of a quadrature. The last multiplier will be 1 for all problems where a W exists. In the second part of the paper it will be shown that the laws of Weber and Riemann allow a complete solution of the problem of two bodies, whereas Clausius's law does not, since there exist but seven integrals in that case.

Professor A. Mayer, of Leipzig, has published a very important paper bearing on a similar subject in the Berichte der *Kgl. Sächs. Gesellsch. der Wissenschaften*, 1877 April 23 (reprinted in the XIII volume of the *Mathematische Annalen*, p. 20). He considers the most general expression of interior Effective Potential Forces which fulfil the principle of action and reaction. He does not consider the forces to result from the mutual action of the bodies *in pairs* but assumes that the forces fulfil in every moment the six equations of equilibrium of a solid, namely:

$$\sum_1^n X_i = 0 \qquad \sum Y_i = 0 \qquad \sum Z_i = 0$$

$$\sum_1^n (y_i Z_i - z_i Y_i) = 0 \qquad \sum (z_i X_i - x_i Z_i) = 0$$

$$\sum (x_i Y_i - y_i X_i) = 0$$

The result of his investigation is that W should be an arbitrary function of the time, the mutual distances of the bodies and their first differentials with respect to the time. In making the system fulfil the principle of conservation of *vis viva* the further condition is imposed that t does not enter explicitly into W. The motion of the center of gravity is in a straight line and is uniform, and the theorem of conservation of areas holds for all of the co-ordinate planes. It will be seen in the case now under consideration that neither the principle of *conservation* of the motion of the center of gravity nor that of *conservation* of areas necessarily holds, but that functions of the time will occur on the right sides, whereas in Professor Mayer's problem they have constant values. Very valuable suggestions have been obtained from Professor Mayer's paper, to which due acknowledgment is expressed.

Part I. The Ten Integrals.

I. *The Motion of the Center of Gravity.*

In equation (a) we give the following special values to the virtual displacements:

$$\delta x_1 = \delta x_2 = \ldots = \delta x_n = \lambda$$
$$\delta y_1 = \delta y_2 = \ldots = \delta y_n = \mu$$
$$\delta z_1 = \delta z_2 = \ldots = \delta z_n = \nu$$

and introduce the values of X_i, Y_i, Z_i from system (d). Then we obtain (1)

$$\lambda \sum_1^n i\left\{ m_i \frac{d^2x_i}{dt^2} - \left[\frac{\partial W}{\partial x_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial x_i'}\right)\right]\right\} + \mu \sum_1^n i\left\{ m_i \frac{d^2y_i}{dt^2} - \left[\frac{\partial W}{\partial y_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial y_i'}\right)\right]\right\} + \nu \sum_1^n i\left\{ m_i \frac{d^2z_i}{dt^2} - \left[\frac{\partial W}{\partial z_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial z_i'}\right)\right]\right\} = 0$$

Since λ, μ, ν are independent displacements this equation can be fulfilled only if their coefficients are separately zero:

$$(2)\qquad \begin{aligned} \sum_1^n i\, m_i \frac{d^2x_i}{dt^2} &= \sum_1^n i\left[\frac{\partial W}{\partial x_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial x_i'}\right)\right] \\ \sum_1^n i\, m_i \frac{d^2y_i}{dt^2} &= \sum_1^n i\left[\frac{\partial W}{\partial y_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial y_i'}\right)\right] \\ \sum_1^n i\, m_i \frac{d^2z_i}{dt^2} &= \sum_1^n i\left[\frac{\partial W}{\partial z_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial z_i'}\right)\right] \end{aligned}$$

We can integrate these equations once if

$$\sum \frac{\partial W}{\partial x_i},\ \sum \frac{\partial W}{\partial y_i},\ \sum \frac{\partial W}{\partial z_i}$$

can be presented in the form of total differentials, since the other term of the right-hand side presents itself already in this way. We must therefore solve the equation

$$\sum \frac{\partial W}{\partial x_i} = \frac{df}{dt} \tag{3}$$

Since W is a function in which no second differentials appear $\sum \frac{\partial W}{\partial x_i}$ will have the same property, and we observe that f must be a function of the time and the co-ordinates but not of the velocities. Regarding ψ as an arbitrary function of the time and the co-ordinates, we see that $W = \frac{d\psi}{dt}$ will satisfy the equation above on account of the properties A and B indicated above. Indeed we obtain $\frac{d}{dt}\sum \frac{\partial \psi}{\partial x_i} = \frac{df}{dt}$ To find the general

solution we put $W = \frac{d\psi}{dt} + V$ and determine the character of V by putting this expression into (3). We thus obtain

$$(4) \qquad \sum \frac{\partial V}{\partial x_i} = 0$$

To obtain the general integral of this partial differential equation we consider the system of total differential equation to which the partial differential equation is equivalent.

$$(5) \qquad dx_1 : dx_2 : \ldots : dx_n = 1$$

The $(n-1)$ integrals of this system are

$$(6) \qquad f_2 = (x_2 - x_1) = c_2 \qquad f_3 = (x_3 - x_1) = c_3 \ldots \quad f_n = (x_n - x_1) = c_n$$

$V(f_2, f_3, \ldots f_n)$ will therefore be the general integral of (4) and $W = \frac{d\psi}{dt} + V$ the general integral of (3). Applying the same reasoning for the y and z co-ordinates we learn that V should be a function of the differences of the co-ordinates of the bodies in order that three integrals of the differential equations of motion may be obtained. We can therefore integrate system (2) once, and obtain after reduction

$$(2^a) \qquad \begin{aligned} \sum m_i \frac{dx_i}{dt} &= -\sum \frac{\partial V}{\partial x_i'} + \alpha_1 = M\frac{dA}{dt} \\ \sum m_i \frac{dy_i}{dt} &= -\sum \frac{\partial V}{\partial y_i'} + \beta_1 = M\frac{dB}{dt} \\ \sum m_i \frac{dz_i}{dt} &= -\sum \frac{\partial V}{\partial z_i'} + \gamma_1 = M\frac{dC}{dt} \end{aligned}$$

We have introduced by $M = \Sigma m_i$, $MA = \Sigma m_i x_i$, $MB = \Sigma m_i y_i$, $MC = \Sigma m_i z_i$, the mass M and co-ordinates A, B, C of the center of gravity of the system. It is obvious that the principle of conservation of the motion of the center of gravity ceases to hold in this case, since V is an arbitrary function of the time and the velocities.

To obtain three more integrals we investigate the condition

$$(3^a) \qquad \sum \frac{\partial V}{\partial x'_i} = \frac{dq}{dt}$$

$q = q$ (co-ordinates, t) since $\sum \frac{\partial V}{\partial x'_i}$ cannot contain second differentials. To solve this problem we take an arbitrary function $q = q$ (co-ordinates, t) then is $\frac{dq}{dt}$ of the character of V. If we introduce $V = \frac{dq}{dt}$ into (3^a) we obtain

$$\sum \frac{\partial\left(\frac{dq}{dt}\right)}{\partial x_i'} = \frac{dq}{dt} \quad \text{or on account of } (B) \quad \sum \frac{\partial q}{\partial x_i} = \frac{dq}{dt}$$

On the left side enters a function of the co-ordinates and the time alone, on the right side, according to our assumption a function of the velocities, co-ordinates and the time. This cannot hold otherwise than by assuming

$$q = \int \chi \text{ (co-ordinates, } t) \, dt$$

We are therefore led to $\sum \frac{\partial q}{\partial x_i} = \chi$ (co-ordinates, t). From this equation we determine q and have for the general integral of (3^a) the function $V = \frac{dq}{dt} + V_1$. We then obtain for V_1 the partial differential equation

$$\sum \frac{\partial V_1}{\partial x_i'} = 0 \qquad (4^a)$$

To this belongs the system of total differential equations

$$dx_1' : dx_2' : \ldots : dx_n' = 1 \qquad (5^a)$$

The $n-1$ integrals are

$$h_2 = (x_2' - x_1') = d_2 \qquad h_3 = (x_3' - x_1') = d_3 \ldots \quad h_n = (x_n' - x_1') = d_n \qquad (6^a)$$

$V_1(h_2, \ldots h_n)$ will be the general integral of (4^a) and $V = \frac{dq}{dt} + V_1$ that one of (3^a). Applying the same reasoning for the y and z co-ordinates we find finally that the general form of W should be $W = \frac{d\psi}{dt} + V$ in order that the *six* integrals should exist. V is an arbitrary function of the time and the *differences* of the co-ordinates and of the velocities. Equations (2^a) when integrated take the form

$$\begin{aligned} MA &= \sum m_i x_i = \alpha_2 + \alpha_1 t - \int \sum \frac{\partial q}{\partial x_i} dt \\ MB &= \sum m_i y_i = \beta_2 + \beta_1 t - \int \sum \frac{\partial q}{\partial y_i} dt \\ MC &= \sum m_i z_i = \gamma_2 + \gamma_1 t - \int \sum \frac{\partial q}{\partial z_i} dt \end{aligned}$$

II. *The Integrals of Areas.*

To obtain the next three integrals, which will correspond to the integrals of *conservation* of areas, we put

$$\delta x_i = 0 \;,\; \delta y_i = -z_i \, \delta v \;\cdot\; \delta z_i = y_i \, \delta v$$

and obtain

$$(7) \qquad \sum m_i \left\{ y_i \frac{d^2 z_i}{dt^2} - z_i \frac{d^2 y_i}{dt^2} \right\} = \sum \left\{ y_i \frac{\partial W}{\partial z_i} - z_i \frac{\partial W}{\partial y_i} + y_i' \frac{\partial W}{\partial z_i'} - z_i' \frac{\partial W}{\partial y_i'} \right\} - \frac{d}{dt} \sum \left\{ y_i \frac{\partial W}{\partial z_i'} - z_i \frac{\partial W}{\partial y_i'} \right\}$$

The other two equations which form with (7) a system of three equations are obtained by permuting the co-ordinates in the last equation. To integrate (7) we require that

$$\sum \left\{ y_i \frac{\partial W}{\partial z_i} - z_i \frac{\partial W}{\partial y_i} + y_i' \frac{\partial W}{\partial z_i'} - z_i' \frac{\partial W}{\partial y_i'} \right\} = \frac{dF}{dt} \qquad (8)$$

where evidently F is a function of the time and the

co-ordinates alone. Considering ψ to be such a function we put $W = \frac{d\psi}{dt}$ and obtain after reduction

$$\frac{d}{dt}\sum\left\{y_i\frac{\partial\psi}{\partial z_i} - z_i\frac{\partial\psi}{\partial y_i}\right\} = \frac{dF}{dt}$$

We determine therefore ψ from the equation

$$\sum\left\{y_i\frac{\partial\psi}{\partial z_i} - z_i\frac{\partial\psi}{\partial y_i}\right\} = F + \text{const.}$$

and put $W = \frac{d\psi}{dt} + V$ into (8) to find the properties of V. We are led to the partial differential equation of the first order,

$$\sum\left\{y_i\frac{\partial V}{\partial z_i} - z_i\frac{\partial V}{\partial y_i} + y_i'\frac{\partial V}{\partial z_i'} - z_i'\frac{\partial V}{\partial y_i'}\right\} = 0 \qquad (9)$$

$4n$ independent variables enter into (9). The system of total differential equations of the first order equivalent to (9) is

$$\begin{matrix} dz_1 : dz_2 : \ldots : dz_n & ; & dy_1 : dy_2 : \ldots : dy_n & ; & dz_1' : dz_2' : \ldots : dz_n' & ; & dy_1' : dy_2' : \ldots : dy_n' = \\ y_1 : y_2 : \ldots : y_n & ; & -z_1 : -z_2 : \ldots : -z_n & ; & y_1' : y_2' : \ldots : y_n' & ; & -z_1' : -z_2' : \ldots : z_n' \end{matrix} \qquad (10)$$

The $4n-2$ integrals of this system are

$$\underset{n \text{ integrals}}{z_i^2 + y_i^2 = a_i} \qquad \underset{n-1 \text{ integrals}}{z_i z_k + y_i y_k = b_{ik}} \qquad \underset{n \text{ integrals}}{y_i'^2 + z_i'^2 = c_i} \qquad \underset{n-1 \text{ integrals}}{z_i' z_k' + y_i' y_k' = d_{ik}}$$

The general integral of (9) is therefore a function

$$V = V(z_i^2+y_i^2,\, z_i z_k + y_i y_k\,;\, z_i'^2+y_i'^2,\, z_i' z_k' + y_i' y_k')$$

$V + \frac{d\psi}{dt} = W$ will be the integral of (8). The other two equations which are derived from (7) by permutation of $z_i\, y_i\, z_i$ will finally lead us to the result that V must be a function of

$$r_i^2,\; x_i x_k + y_i y_k + z_i z_k\;;\; v_i^2,\; x_i' x_k' + y_i' y_k' + z_i' z_k'$$

where we have put $r_i^2 = x_i^2 + y_i^2 + z_i^2$ and $v_i^2 = x_i'^2 + y_i'^2 + z_i'^2$

The integration of the three equations (7) leads to the following result:

$$\sum m_i\left(y_i\frac{dz_i}{dt} - z_i\frac{dy_i}{dt}\right) = \alpha_3 - \sum\left(y_i\frac{\partial V}{\partial z_i'} - z_i\frac{\partial V}{\partial y_i'}\right)$$

$$\sum m_i\left(z_i\frac{dx_i}{dt} - x_i\frac{dz_i}{dt}\right) = \beta_3 - \sum\left(z_i\frac{\partial V}{\partial x_i'} - x_i\frac{\partial V}{\partial x_i'}\right) \qquad (11)$$

$$\sum m_i\left(x_i\frac{dy_i}{dt} - y_i\frac{dx_i}{dt}\right) = \gamma_3 - \sum\left(x_i\frac{\partial V}{\partial y_i'} - y_i\frac{\partial V}{\partial x_i'}\right)$$

III. *The Principle of Conservation of Vis Viva.*

Letting $\delta x_i = \frac{dx_i}{dt}dt \quad \delta y_i = \frac{dy_i}{dt}dt \quad \delta z_i = \frac{dz_i}{dt}dt$ we obtain (12)

$$\frac{d}{dt}\left[\frac{1}{2}\sum m_i\left\{\left(\frac{dx_i}{dt}\right)^2 + \left(\frac{dy_i}{dt}\right)^2 + \left(\frac{dz_i}{dt}\right)^2\right\}\right] = \sum\left\{\left[\frac{\partial W}{\partial x_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial x_i'}\right)\right]\frac{dx_i}{dt} + \left[\frac{\partial W}{\partial y_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial y_i'}\right)\right]\frac{dy_i}{dt} + \left[\frac{\partial W}{\partial z_i} - \frac{d}{dt}\left(\frac{\partial W}{\partial z_i'}\right)\right]\frac{dz_i}{dt}\right\}dt$$

Or after integration we obtain

$$T = \int\sum\left\{\frac{\partial W}{\partial x_i}x_i' + \frac{\partial W}{\partial y_i}y_i' + \frac{\partial W}{\partial z_i}z_i'\right\}dt - \int\sum\left\{d\left(\frac{\partial W}{\partial x_i'}\right).x_i' + d\left(\frac{\partial W}{\partial y_i'}\right).y_i' + d\left(\frac{\partial W}{\partial z_i'}\right)z_i'\right\} + h$$

$$T = \int\sum\left\{\frac{\partial W}{\partial x_i}x_i' + \frac{\partial W}{\partial y_i}y_i' + \frac{\partial W}{\partial z_i}z_i' + \frac{\partial W}{\partial x_i'}x_i'' + \frac{\partial W}{\partial y_i'}y_i'' + \frac{\partial W}{\partial z_i'}z_i''\right\}dt - \sum\left\{\frac{\partial W}{\partial x_i'}x_i' + \frac{\partial W}{\partial y_i'}y_i' + \frac{\partial W}{\partial z_i'}z_i'\right\} + h$$

The expression under the integral sign is equal to

$$\left(\frac{dW}{dt} - \frac{\partial W}{\partial t}\right)dt$$

so that we get

$$T = W - \int\frac{\partial W}{\partial t}dt + \sum\left\{\frac{\partial W}{\partial x_i'}x_i' + \frac{\partial W}{\partial y_i'}y_i' + \frac{\partial W}{\partial z_i'}z_i'\right\} + h$$

It is evident that the expression $\int\frac{\partial W}{\partial t}dt$ will disappear in this last expression if we assume in $W = \frac{d\psi}{dt} + V$ that V does not contain t explicitly. We thus obtain

$$T = \frac{d\psi}{dt} + V - \frac{\int\partial\left(\frac{d\psi}{dt}\right)}{\partial t}dt - \sum\left\{\frac{\partial V}{\partial x_i'}x_i' + \frac{\partial V}{\partial y_i'}y_i' + \frac{\partial V}{\partial z_i'}z_i'\right\} - \sum\left\{\frac{\partial\left(\frac{d\psi}{dt}\right)}{\partial x_i'}x_i' + \partial\frac{\left(\frac{d\psi}{dt}\right)}{\partial y_i'}y_i' + \partial\frac{\left(\frac{d\psi}{dt}\right)}{\partial z_i'}z_i'\right\} + h \text{ or}$$

$$T = \frac{d\psi}{dt} + V - \frac{\partial\psi}{\partial t} - \sum\left\{\frac{\partial V}{\partial x_i'}x_i' + \frac{\partial V}{\partial y_i'}y_i' + \frac{\partial V}{\partial z_i'}z_i'\right\} - \sum\left\{\frac{\partial\psi}{\partial x_i}\cdot\frac{dx_i}{dt} + \frac{\partial\psi}{\partial y_i}\cdot\frac{dy_i}{dt} + \frac{\partial\psi}{\partial z_i}\cdot\frac{dz_i}{dt}\right\} + h$$

The last term on the right-hand member in connection with $-\frac{\partial\psi}{\partial t}$ equals $-\frac{d\psi}{dt}$, so that we obtain

$$(13) \qquad T = V - \sum\left\{\frac{\partial V}{\partial x_i'}x_i' + \frac{\partial V}{\partial y_i'}y_i' + \frac{\partial V}{\partial z_i'}z_i'\right\} + h$$

If V is a homogeneous function of the nth degree in x_i', y_i', z_i' we obtain

$$(14) \qquad T = (1-n)V + h$$

In order that the ten integrals should subsist at the same time we have to regard V as a function of the mutual distances, and the relative velocities of the n bodies, then all of the conditions under I, II and III will be fulfilled. It is important to remark that the four integrals of relative motion — with respect to the center of gravity — will hold good as long as the ten integrals of absolute motion exist. The proof is substantially the same as that one given in the textbooks on Dynamics.

Part II. The Integration of the Differential Equations of Motion of the Problem of Two Bodies.

The problem of two bodies being of the 12th order we shall be able to solve it completely if the last two integrals can be obtained by means of Jacobi's principle of the last multiplier. We shall see that this principle applies for Effective Potential Forces.

$W = W(r, v)$ where $r^2 = x^2+y^2+z^2 \quad v^2 = x'^2+y'^2+z'^2$, in this part of the paper where no ambiguity is possible, x, y, z will be used for relative co-ordinates. We have for relative motion the three differential equations:

$$(1) \quad \frac{d^2x}{dt^2} = \frac{\partial W}{\partial x} - \frac{d}{dt}\left(\frac{\partial W}{\partial x'}\right), \quad \frac{d^2y}{dt^2} = \frac{\partial W}{\partial y} - \frac{d}{dt}\left(\frac{\partial W}{\partial y'}\right)$$
$$\frac{d^2z}{dt^2} = \frac{\partial W}{\partial z} - \frac{d}{dt}\left(\frac{\partial W}{\partial z'}\right)$$

Introducing $W = W(r, v)$ we obtain

$$(2) \quad x'' = \frac{\partial W}{\partial r}\cdot\frac{x}{r} - \frac{d}{dt}\left(\frac{\partial W}{\partial v}\right)\frac{x'}{v} + \frac{\partial W}{\partial v}\frac{x''}{v} - \frac{\partial W}{\partial v}(x'x''+y'y''+z'z'')\frac{x'}{v^2}$$

and two other equations similar to this one.

Let system (2) be solved for x'', y'' and z'' so that we obtain

$$(3) \quad x'' = G \qquad y'' = H \qquad z'' = L$$

where G, H, L are functions of the co-ordinates and their first differentials.

This system can be replaced by the following one:

$$(4) \quad dt : dx : dx' : dy : dy' : dz : dz' = 1 : x' : G : y' : H : z' : L$$

Since G, H, L do not contain t explicitly we can eliminate the time from the last system by omitting on the left side dt and on the right side 1. We obtain therefore the system of the fifth order

$$(5) \quad dx : dx' : dy : dy' : dz : dz' = x' : G : y' : H : z' : L$$

After having solved this system completely and having expressed x', y, y', z, z' in terms of x and the five constants of integration, we obtain x, x', y, y', z, z' finally expressed in terms of t and the six constants of integration by solving the quadrature

$$(6) \qquad t = \int\frac{dx}{x'} + C_6$$

Since but four integrals are known for system (5) we have to search for the last multiplier of the last differential equation. Jacobi has shown that this multiplier can be obtained in all cases where $\frac{\partial G}{\partial x'}+\frac{\partial H}{\partial y'}+\frac{\partial L}{\partial z'}$ is a total differential quotient. The transformation of (2) into (3) is generally not an easy matter, and the general proof that $\frac{\partial G}{\partial x'}+\frac{\partial H}{\partial y'}+\frac{\partial L}{\partial z'}$ is a total differential quotient seems to be difficult. But we can obviate this difficulty readily if we employ canonical co-ordinates. We need not limit ourselves to the problem of two bodies, but can prove the theorem for that of n bodies. Indeed from equations (h), where a extends from 1 to n, we obtain the differential equations of motion in the form of a proportion:

$$dt : dq_1 : dq_2 : \ldots : dq_{3n} : dp_1 : dp_2 : \ldots : dp_{3n} \tag{7}$$
$$= 1 : \frac{\partial K}{\partial p_1} : \frac{\partial K}{\partial p_2} : \ldots : \frac{\partial K}{\partial p_{3n}} : -\frac{\partial K}{\partial q_1} - \frac{\partial K}{\partial q_2} : \ldots : -\frac{\partial K}{\partial q_{3n}}$$

Applying formula (5) of the fourteenth chapter of the *Vorlesungen* to equation (7) and calling N the last multiplier we obtain

$$0 = \frac{d\log N}{dt} + \sum_1^{3n}{}_a \frac{\partial\left(\frac{\partial K}{\partial p_a}\right)}{\partial q_a} + \sum_1^{3n}{}_a \frac{\partial\left(-\frac{\partial K}{\partial q_a}\right)}{\partial p_a} \tag{8}$$

since $\frac{\partial^2 K}{\partial q_a \partial p_a} - \frac{\partial^2 K}{\partial p_a \partial q_a} = 0$ we obtain a solution of (8) in the form

$$N = \text{const.} \tag{9}$$

If therefore $6n-2$ integrals are obtained we can find the last two integrals. Indeed t enters into (7) through its differential alone and the multiplier of the last differential equation is obtained from the $6n-2$ integrals that are known. Calling the $6n-2$ integral equations

$$\omega_1 = 0 \quad \omega_2 = 0 \quad \ldots \quad \omega_{6n-2} = 0 \tag{10}$$

we obtain the last multiplier in the form of the quotient of two functional determinants:

$$\frac{\sum \pm \frac{\partial\omega_1}{\partial c_1}\frac{\partial\omega_2}{\partial c_2}\cdots\frac{\partial\omega_{6n-2}}{\partial c_{6n-2}}}{\sum \pm \frac{\partial\omega_1}{\partial q_3}\frac{\partial\omega_2}{\partial q_3}\cdots\frac{\partial\omega_{3n-2}}{\partial q_{3n}}\frac{\partial\omega_{3n-1}}{\partial p_1}\cdots\frac{\partial\omega_{6n-2}}{\partial p_{3n}}} \tag{11}$$

$c_1, c_2, \ldots c_{6n-2}$ are the arbitrary constants of integration of system (10).

The last differential equation for which (11) is the expression of its last multiplier is

$$\frac{\partial K}{\partial p_1}dq_2 - \frac{\partial K}{\partial p_2}dq_1 = 0 \tag{12}$$

Applying the foregoing result to the problem under consideration, the problem of two bodies, we obtain the following theorem: *The differential equations of motion of the problem of two bodies can always be integrated completely for Effective Potential Forces if the Effective Potential has the form* $W = V(r, v) + \frac{d\psi}{dt}$

Applications.

Let us illustrate the foregoing results by a study of the three electrodynamical laws of Weber, Riemann and Clausius.

(A) *The Law of* Weber.

$$V = \sum_i\sum_j \frac{m_i m_j}{r_{ij}}\left\{1 + \frac{1}{c^2}\left(\frac{dr_{ij}}{dt}\right)^2\right\}$$

For this potential the principle of action and reaction holds and the conditions which Professor A. Mayer has found are satisfied by V: it depends on r_{ij} and r_{ij}' and besides does not contain t explicitly. The center of gravity

will therefore move in a straight line with uniform velocity and the principle of conservation of areas is fulfilled for the three co-ordinate planes.

The principle of conservation of *vis viva* is expressed by

$$T=\sum\sum\frac{m_i m_j}{r_{ij}}\left\{1+\frac{r_{ij}'^2}{c^2}\right\}-\sum\left(x'\frac{\partial V}{\partial x'}+y'\frac{\partial V}{\partial y'}+z'\frac{\partial V}{\partial z'}\right)+h$$

When we break up V into two parts so that $V=V_1+V_2$ we have

$$V_1=\sum\sum\frac{m_i m_j}{r_{ij}}\qquad V_2=\sum\sum\frac{m_i m_j}{r_{ij}c^2}\,r_{ij}'^2$$

V_2 is a homogeneous function of x', y', z' of the second degree and we obtain

$$T=V_1-V_2+h=\sum\sum\frac{m_i m_j}{r_{ij}}\left\{1-\frac{r_{ij}'^2}{c^2}\right\}+h$$

Professor C. NEUMANN calls V_1 the "statical," V_2 the "dynamical" part of the effective Potential (NEWTON's *Princip* . . . . p. 235).

For the problem of two bodies we have

$$V=\frac{k^2}{r}\left(1+\frac{r'^2}{c^2}\right) \tag{12}$$

where k^2 is GAUSS's constant (it should be said that c^2 is a very large quantity). The differential equations of motion are

$$\begin{aligned}\frac{d^2x}{dt^2}&=-\frac{k^2x}{r^3}\left\{1-\frac{1}{c^2}\left(\frac{dr}{dt}\right)^2+\frac{2r}{c^2}\frac{d^2r}{dt^2}\right\}\\ \frac{d^2y}{dt^2}&=-\frac{k^2y}{r^3}\left\{1-\frac{1}{c^2}\left(\frac{dr}{dt}\right)^2+\frac{2r}{c^2}\frac{d^2r}{dt^2}\right\}\end{aligned} \tag{13}$$

Since the principle of conservation of areas holds, we have selected the plane of motion as xy plane. Introduce polar co-ordinates by putting

$$x=r\cos\vartheta\quad,\quad y=r\sin\vartheta \tag{14}$$

we obtain after a simple reduction* (15)

$$\frac{d^2r}{dt^2}=\frac{1}{1+\dfrac{2k^2}{rc^2}}\left\{r\left(\frac{d\vartheta}{dt}\right)^2-\frac{k^2}{r^2}\left(1-\frac{1}{c^2}\left(\frac{dr}{dt}\right)^2\right)\right\}=G$$

$$\frac{d^2\vartheta}{dt}=-\frac{2}{r}\frac{dr}{dt}\cdot\frac{d\vartheta}{dt}=H$$

We see easily that

$$\frac{\partial G}{\partial r'}+\frac{\partial H}{\partial\vartheta'}=-2\left\{\frac{1}{2r+r^2\dfrac{c^2}{k^2}}+\frac{1}{\dfrac{2k^2}{c^2}+r}\right\}\frac{dr}{dt}=\frac{df(r)}{dt}.$$

The two integrals (15) which we know are (16)

$$r^2\frac{d\vartheta}{dt}=\gamma_3\ \text{ and }\ \left(\frac{dr}{dt}\right)^2+r^2\left(\frac{d\vartheta}{dt}\right)^2-\frac{2k^2}{r}\left(1-\frac{1}{c^2}\left(\frac{dr}{dt}\right)^2\right)=h$$

The second equation of (15) is the differential of the first of (16) so that system (15) is transformed into a system of the third order

$$\begin{aligned}\frac{d^2r}{dt^2}&=\frac{1}{1+\dfrac{2k^2}{rc^2}}\left\{\frac{\gamma_3^2}{r^3}-\frac{k^2}{r^2}\left(1-\frac{1}{c^2}\left(\frac{dr}{dt}\right)^2\right)\right\}\\ r^2\frac{d\vartheta}{dt}&=\gamma_3\end{aligned} \tag{17}$$

or in the form of a proportion

$$dt:dr:dr':d\vartheta=1:r':\frac{\dfrac{\gamma_3^2}{r^3}-\dfrac{k^2}{r^2}\left(1-\dfrac{r'^2}{c^2}\right)}{1+\dfrac{2k^2}{rc^2}}:\frac{\gamma_3}{r^2} \tag{18}$$

Eliminate t by means of

$$dt=\frac{dr}{r'} \tag{19}$$

and we obtain

$$dr:dr':d\vartheta=r':\frac{\gamma_3^2-k^2r\left(1-\dfrac{r'^2}{c^2}\right)}{r^3+2r^2\dfrac{k^2}{c^2}}:\frac{\gamma_3}{r^2} \tag{20}$$

The first of these equations, namely,

$$dr:dr'=r':\frac{\gamma_3^2-k^2r\left(1-\dfrac{r'^2}{c^2}\right)}{r^3+2r^2\dfrac{k^2}{c^2}}$$

is the differential of the $(16)_2$ when dt is eliminated through (19).

There is left therefore for integration the following differential equation $dr:d\vartheta=r':\frac{\gamma_3}{r^2}$. From $(16)_2$ we have

$$r'=\pm\sqrt{\frac{h-\dfrac{\gamma_3^2}{r^2}+\dfrac{2k^2}{r}}{1+\dfrac{2k^2}{rc^2}}} \tag{21}$$

Introducing this in the equation above we obtain

$$d\vartheta=\frac{\gamma_3\,dr}{\pm r^2\sqrt{\dfrac{h-\dfrac{\gamma_3^2}{r^2}+\dfrac{2k^2}{r}}{1+\dfrac{2k^2}{rc^2}}}}.$$

We can evidently integrate this equation completely without determining the last multiplier from $(16)_1$ and $(16)_2$ and obtain thus finally the four variables $r, r', \vartheta, \vartheta'$ from the following integral equations: (22)

$$t+t_0=\int\frac{\sqrt{1+\dfrac{2k^2}{rc^2}}}{\sqrt{h+\dfrac{2k^2}{r^2}-\dfrac{\gamma_3^2}{r^2}}}\,dr\ ,\quad \vartheta+\vartheta_0=\int\frac{\gamma_3\sqrt{1+\dfrac{2k^2}{rc^2}}}{r^2\sqrt{h+\dfrac{2k^2}{r}-\dfrac{\gamma_3^2}{r^2}}}$$

$$r'=\frac{\sqrt{h+\dfrac{2k^2}{r}-\dfrac{\gamma_3^2}{r^2}}}{\sqrt{1+\dfrac{2k^2}{rc^2}}}\quad,\quad \vartheta'=\frac{\gamma_3}{r^2}$$

For the evaluation of the elliptic integrals see SEEGER's *De motu perturbationibusque planetarum*, etc. Göttingen, 1864.

(B) *The Law of* RIEMANN.

The effective Potential takes the form

$$V=\sum\sum\frac{m_i m_j}{r_{ij}}\left\{1+\frac{r_{ij}'^2}{c^2}\right\} \tag{23}$$

Since $W=V$ is fulfilled and

$$\sum\frac{\partial V}{\partial x_i'}=0\quad\sum\frac{\partial V}{\partial y_i'}=0\quad\sum\frac{\partial V}{\partial z_i'}=0$$

we see that the center of gravity will move with uniform velocity in a straight line. The principle of conservation of areas does not hold.

We obtain instead of it the equations

* See my paper: *On the Integration of the Differential Equations of Motion in the Problem of Two Bodies* (*The Astronomical Journal*, No. 394, Part II.)

$$(24)\quad \begin{aligned} \sum m_i\left(y_i\frac{dz_i}{dt}-z_i\frac{dy_i}{dt}\right) &= \alpha_3-\sum\sum\frac{m_i m_j}{r_{ij}c^2}\left\{y_i(z_i'-z_j')-z_i(y_i'-y_j')\right\} \\ \sum m_i\left(z_i\frac{dx_i}{dt}-x_i\frac{dz_i}{dt}\right) &= \beta_3-\sum\sum\frac{m_i m_j}{r_{ij}c^2}\left\{z_i(x_i'-x_j')-x_i(z_i'-z_j')\right\} \\ \sum m_i\left(x_i\frac{dy_i}{dt}-y_i\frac{dx_i}{dt}\right) &= \gamma_3-\sum\sum\frac{m_i m_j}{r_{ij}c^2}\left\{x_i(y_i'-y_j')-y_i(x_i'-x_j')\right\} \end{aligned}$$

The principle of *vis viva* is given by

$$(25)\quad T = \sum\sum\frac{m_i m_j}{r_{ij}}\left\{1+\frac{V_{ij}^2}{c^2}\right\}$$

$$-2\sum\sum\left\{(x_i'-x_j')x_i'+(y_i'-y_j')y_i'+(z_i'-z_j')z_i'\right\}+h$$

For the problem of two bodies we obtain

$$V = \frac{k^2}{r}\left\{1+\frac{V^2}{c^2}\right\}$$

Equations (24) and (25) are reduced for $n = 2$ to the following equations:

$$(26)\quad y\frac{dz}{dt}-z\frac{dy}{dt} = \frac{\alpha_3}{1+\frac{2k^2}{rc^2}}\ ,\quad z\frac{dx}{dt}-x\frac{dz}{dt} = \frac{\beta_3}{1+\frac{2k^2}{rc^2}}$$

$$x\frac{dy}{dt}-y\frac{dx}{dt} = \frac{\gamma_3}{1+\frac{2k^2}{rc^2}}$$

$$(27)\quad \left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2+\left(\frac{dz}{dt}\right)^2 = \frac{\frac{2k^2}{r}+h}{1+\frac{2k^2}{rc^2}}$$

Multiplying the three equations (26) by x, y, z respectively and adding we obtain $0 = \dfrac{\alpha_3 x+\beta_3 y+\gamma_3 z}{1+\frac{2k^2}{rc^2}}$

This equation shows that the motion of the second body takes place in a plane which passes through the origin: the primary body. Taking the plane of motion for the xy plane we have to integrate the following system of the fourth order:

$$(28)\quad \begin{aligned} \frac{d^2x}{dt^2} &= -\frac{k^2x}{r^3}-\frac{k^2}{c^2}\left\{\frac{x}{r^3}v^2-\frac{2}{r^2}\frac{dx}{dt}\frac{dr}{dt}+\frac{2}{r}\frac{d^2x}{dt^2}\right\} \\ \frac{d^2y}{dt^2} &= -\frac{k^2y}{r^3}-\frac{k^2}{c^2}\left\{\frac{y}{r^3}v^2-\frac{2}{r^2}\frac{dy}{dt}\frac{dr}{dt}+\frac{2}{r}\frac{d^2y}{dt^2}\right\} \end{aligned}$$

Dealing with this problem in the same way as we did before in WEBER's law, we are led finally to the following system of integral equations:

$$(29)\quad \left\{\begin{aligned} t+t_0 &= \int\left(1+\frac{2k^2}{rc^2}\right)\frac{dr}{\sqrt{\left(\frac{2k^2}{r}+h\right)\left(1+\frac{2k^2}{rc^2}\right)-\frac{\gamma_3^2}{r^2}}} \\ \vartheta+\vartheta_0 &= \gamma_3\int\frac{dr}{r^2\sqrt{\left(\frac{2k^2}{r}+h\right)\left(1+\frac{2k^2}{rc^2}\right)-\frac{\gamma_3^2}{r^2}}} \\ r' &= \frac{1}{1+\frac{2k^2}{rc^2}}\sqrt{\left(\frac{2k^2}{r}+h\right)\left(1+\frac{2k^2}{rc^2}\right)-\frac{\gamma_3^2}{r^2}} \\ \vartheta' &= \frac{\gamma_3}{r^2\left(1+\frac{2k^2}{rc^2}\right)} \end{aligned}\right.$$

A discussion of these equations is given in F. TISSERAND *Traité de mécanique céleste*, Tome IV, p. 504–508.

(C) *The Law of* CLAUSIUS.

The effective potential is

$$V = \sum\sum\frac{m_i m_j}{r_{ij}}\left\{1+\sigma\left[\frac{dx_i}{dt}\frac{dx_j}{dt}+\frac{dy_i}{dt}\frac{dy_j}{dt}+\frac{dz_i}{dt}\frac{dz_j}{dt}\right]\right\}$$

where σ is a constant. This potential leads in the simplest of the three laws which R. CLAUSIUS has given to his paper, *Sur la déduction d'un nouveau principe de l'Electrodynamique* (*Journal de Mathématiques pures et appliqués; Troisième Série*, Tome IV, p. 113 [French translation by Mr. F. FOLIE]).

Since we have

$$\frac{dx_i}{dt}\frac{dx_j}{dt}+\frac{dy_i}{dt}\frac{dy_j}{dt}+\frac{dz_i}{dt}\frac{dz_j}{dt} = \tfrac{1}{2}\left\{V_i^2+V_j^2-V_{ij}^2\right\}$$

and $\qquad r_{ij}^2 = (x_i-x_j)^2+(y_i-y_j)^2+(z_i-z_j)^2$

we learn that the following relation will hold:

$$(1)\quad \begin{aligned} \sum\left\{y_i\frac{\partial V}{\partial z_i}-z_i\frac{\partial V}{\partial y_i}+y_i'\frac{\partial V}{\partial z_i'}-z_i'\frac{\partial V}{\partial y_i'}\right\} &= 0 \\ \sum\left\{z_i\frac{\partial V}{\partial x_i}-x_i\frac{\partial V}{\partial z_i}+z_i'\frac{\partial V}{\partial x_i'}-x_i'\frac{\partial V}{\partial z_i'}\right\} &= 0 \\ \sum\left\{x_i\frac{\partial V}{\partial y_i}-y_i\frac{\partial V}{\partial x_i}+x_i'\frac{\partial V}{\partial y_i'}-y_i'\frac{\partial V}{\partial x_i'}\right\} &= 0 \end{aligned}$$

the three integrals of areas will hold. See Part I, No. II.

$$(2)\quad \sum\frac{\partial V}{\partial x_i} = 0\ ,\quad \sum\frac{\partial V}{\partial y_i} = 0\ ,\quad \sum\frac{\partial V}{\partial z_i} = 0$$

the first three integrals of the motion of the center of gravity will hold.

$$(3)\quad \sum\frac{\partial V}{\partial x_i'} \neq 0\ ,\quad \sum\frac{\partial V}{\partial y_i'} \neq 0\ ,\quad \sum\frac{\partial V}{\partial z_i'} \neq 0$$

the last three integrals of the motion of the center of gravity will *not* hold.

Since V does not contain t explicitly the principle of conservation of *vis viva* will hold. We have therefore but seven integrals for absolute motion and can not expect to solve the problem of two bodies.

The University of Chicago, 1898 *July* 24.

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COMPARISON OF THE OBSERVED AND PREDICTED MOTIONS OF THE POLE, 1890–1898, AND DETERMINATION OF REVISED ELEMENTS,

By S. C. CHANDLER.

Several years have elapsed since the geometrical law of the movements of the earth's axis was demonstrated, and its numerical constants ascertained from all the suitable observations from 1825 to 1893. A synopsis of this theory was given in *A.J.* 406. It is proposed in the present article to compare it with the observed motion as derived from the numerous observations, directed to this end, so laboriously executed at many stations during the last eight or nine years; and to ascertain what improvement can now be made in the numerical values of the elements involved in the expression of the law, namely, the periods and dimensions of its two components, with their variations.

It is impracticable in the space available here to give the numerical details of the investigation, or more than a general brief description of its processes. The data employed are the following: —

Station	Observers	Interval	φ_0
			$''$
Tokio	Kimura	1895.6–96.5	16.70
"	Kimura	1896.7–97.7	16.70
Kasan	Kowalski	1892.4–93.5	23.21
"	Gratschew and Trozki	1893.6–95.0	23.14
"	Gratschew	1895.1–97.7	23.08
Pulkowa	Wanach	1890.3–91.4	18.13
"	Kostinsky	1891.7–93.3	18.01
"	Nyrén	1893.2–94.4	18.69
"	Pedaschenko	1896.3–97.5	17.97
Cape G. Hope	Gill and Finlay	1892.2–94.2	3.23
Vienna	Sterneck and Křifka	1892.9–94.0	40.04
Prague	Weinek and Gruss	1889.2–92.4	15.86
"	Spitaler and Leiblein	1895.2–97.7	15.90
Naples	Fergola	1893.4–94.5	45.76
Berlin	Marcuse	1889.0–91.2	17.29
"	Battermann	1891.1–93.0	17.39
Potsdam	Schnauder	1889.0–90.3	56.29
"	Schnauder and Hecker	1893.9–97.5	53.13
Karlsruhe	Ristenpart	1892.8–96.5	28.98
Strassburg	Becker and Kobold	1891.4–96.5	0.15
Lyons	Gonnessiat	1893.3–97.3	40.98
New York	Rees, Jacoby and Davis	1893.3–94.5	27.19
Philadelphia	Doolittle	1896.8–98.2	2.12
Bethlehem	Doolittle	1889.9–91.0	23.33
"	Doolittle	1892.8–95.6	23.11
Rockville	Smith	1891.5–92.6	10.45
San Francisco	Davidson	1891.4–92.6	28.33
Honolulu	Marcuse	1891.4–92.4	24.93
"	Preston	1891.4–92.5	24.39

The data of observation have been used as printed in ALBRECHT's report of the *Centralbureau der Internationalen Erdmessung*, Berlin, 1898; or as kindly communicated to me by several of the observers, whom I desire here to thank for the courtesy. The observed latitudes, after deducting the values of φ_0, properly determined, as given in the above table, were compared with the known formulas (see §7, p. 173, *A.J.* 406), and the deviations combined so as to give mean values at 50-day intervals, for each series, using for such means, in general, dates not more than 25 days from these epochs.

In order to give a perspicuous view of the accordance of the observed latitude-variations with those of the theory, in a condensed form, the accompanying plate, I, has been constructed. By reversing the signs for the series at San Francisco, Honolulu and Tokio, the whole data fall naturally into three groups of longitudes, and by proper reduction can be referred to three meridians, for which I have chosen Kasan, Berlin and Bethlehem. The chart shows, in the broken line, for each group, the mean of the observed latitude-variations reduced to the principal meridian of the group, while the continuous curve is that of the formula.

The correspondence of observation with prediction, for all three meridians, is faithful throughout, as to general character. Nowhere is there any significant systematic departure until the last year, when a difference develops, quite plainly marked in all three, which manifests the need of some correction to the numerical constants of the theory. To ascertain the nature of these corrections I proceeded to determine the observed coordinates of the

pole by processes similar to those originally adopted in *A.J.* 323, 329 for the same purpose. Instead, however, of deducing x and y directly from the latitude-variations themselves, the deviations, O−C, of the observed from the calculated values were made the basis of the computation of corrections, Δx, Δy; thus using the theory as a term of comparison, in an analogous way to that in which an approximate orbit of a planet or comet is employed to unite nearly adjacent observations into normal places. This procedure is as unobjectionable in this case as in the other, since the assumed formulas follow the trajectory of the pole so nearly that the differences are small and their general trend quite regular. This permits the use of obvious and perfectly impartial processes of adjustment which eliminate purely accidental errors, while leaving sway for any actual systematic departures from the general course of the assumed curve. Thus a fair curve is obtained, without sophisticating the observations, whose coordinates represent the actual path of the pole shown by the observations, free from their accidental errors. The adjusted observed values of x, y, thus obtained are given below.

Observed Coordinates of the Pole.

t	x	y	t	x	y
	″	″		″	″
1350	−0.127	+0.195	2800	+0.026	−0.131
1400	+ .090	+ .266	2850	− .001	− .105
1450	+ .246	+ .188	2900	− .022	− .043
1500	+ .255	+ .010	2950	− .044	+ .017
1550	+ .110	− .170	3000	− .064	+ .045
1600	− .090	− .235	3050	− .063	+ .043
1650	− .246	− .138	3100	− .015	+ .013
1700	− .249	+ .068	3150	+ .064	− .017
1750	(− .102)	(+ .257)	3200	+ .122	− .024
1800	(+ .103)	(+ .309)	3250	+ .122	− .011
1850	(+ .245)	(+ .181)	3300	+ .043	+ .005
1900	+ .228	− .032	3350	− .060	+ .002
1950	+ .089	− .218	3400	− .140	− .002
2000	− .090	− .290	3450	− .143	+ .015
2050	− .191	− .224	3500	− .085	+ .058
2100	− .166	− .034	3550	+ .027	+ .098
2150	− .054	+ .152	3600	+ .140	+ .094
2200	+ .092	+ .231	3650	+ .174	+ .033
2250	+ .183	+ .169	3700	+ .111	− .066
2300	+ .180	.000	3750	(− .031)	(− .160)
2350	+ .100	− .164	3800	(− .156)	(− .160)
2400	− .013	− .219	3850	− .210	− .063
2450	− .093	− .151	3900	− .138	+ .064
2500	− .115	− .005	3950	+ .020	+ .171
2550	− .072	+ .122	4000	+ .146	+ .197
2600	− .005	+ .162	4050	+ .175	+ .110
2650	+ .049	+ .113	4100	+ .108	− .050
2700	+ .071	+ .008	4150	−0.003	−0.180
2750	+0.056	−0.092			

The observed curve on the left hand of the accompanying plate II is laid down with the coordinates of the foregoing table; while on the right hand is given the curve of the theory propounded in 1894. This double form of exhibition of the observed and computed paths is adopted to avoid the confusion which would arise, from the involved convolutions of similar curves, if their representation had both been attempted on the same diagram, as was done for the similar case in the plate in *A.J.* 329. The points for each tenth of a year are marked by dots with the small figures against them; the beginning of each year in larger figures.

It will be manifest from a glance at these diagrams that the characteristics of the curves of observation and prediction, both in general and particular, are nearly identical. A less cursory comparison, point by point, will show that what differences exist are of a subordinate nature; that is, they manifestly relate to the need of slight emendation of the numerical constants used, and not to the correctness of the geometrical theory. The only serious departure is in the portions of the curve after the beginning of 1896, after which date the location of the pole of figure by observation is sensibly and systematically behind that of the theory, by an amount corresponding to about 15 or 20 days motion in the orbit.

I now proceed to ascertain what corrections are needed to the computed elements of the motion heretofore used. The problem is to determine from the observed coordinates, x and y, which are entirely independent of theory, the numerical values of the constants, expressing the periods, epochs and parameters in the fundamental equations (27) which represent the geometrical theory of the composite harmonic motion. This problem is not entirely resolvable from this short series alone. The angular velocity, θ, in the 428-day component must be found with precision, and this can only be done by the aid of extraneous data covering a long interval. For this purpose we have recourse to the following table incorporating all of the best material available, namely, all the series of observation since 1825 which are sufficiently precise and sufficiently extended to effect, in each independently, a proper separation of the epochs of the two terms of the latitude-variation.

Column T_1 gives the observed dates, according to the investigations to which reference is made in last column, when the pole of figure passed the Greenwich meridian by virtue of the 428-day revolution. The columns O−C give the deviations from various hypotheses as to the period of this revolution; namely:—

I. Eq. (52) of the investigation in *A.J.* 322, identical with eq. (36) of the synopsis of the theory in *A.J.* 406.

II. The best period variable uniformly with the time which will unite the epoch of the present series with the rest of the data in the table except A; namely,

$$2412646 + 427.0\,E - 0.08\,E^2$$

III. The best similar representation, for the dates since 1860, with a uniform period; namely,

$$241\,2646 + 428.2\,E$$

IV. The formula of H. G. v.d. Sande Bakhuyzen in *A.N.* 3275, namely,

$$241\,2672 + 431.55\,E$$

V. The formula recently given by E. F. v.d. Sande Bakhuyzen in the Proceedings of the Amsterdam Academy,*

$$241\,2660 + 431.11\,E$$

	Observatory	Instrument	Interval	E	T_1	O—C I	O—C II	O—C III	O—C IV	O—C V	Reference
A	Greenwich	Mural Circles	1825–36	−54	238 9521	+40	+166	− 2	+153	+140	*A.J.* 315, eq. (49)
B	Greenwich	Mural Circles	1836–50	−44	239 3712	0	+ 9	− 93	+ 28	+ 20	" 320, " (50)
B	Pulkowa	Prime Vertical	1840–55	−43	239 4148	+11	+ 11	− 85	+ 33	+ 25	" 296, " (43)
B	Pulkowa	Vertical Circle	1842–49	−41	239 4914	−75	− 91	−176	− 64	− 71	" 335, " (14)
C	Pulkowa	Vertical Circle	1863–70	−23	240 2815	+53	+ 32	+ 18	+ 69	+ 70	" 293, " (41)
C	Leyden	Meridian Circle	1864–74	−22	240 3178	−19	− 35	− 47	0	+ 2	*A.N.* 3261
C	Pulkowa	Vertical Circle	1871–75	−17	240 5366	0	+ 2	0	+ 30	+ 34	*A.J.* 293, eq. (42)
D	Pulkowa	Prime Vertical	1875–82	−13	240 7075	−18	− 7	− 4	+ 13	+ 19	" 297, col. 2, line 4
E	Pulkowa	Vertical Circle	1882–89	− 7	240 9654	−11	+ 1	+ 5	+ 3	+ 11	" 426
E	Lyons	Meridian Circle	1885–93	− 4	241 0939	− 3	+ 2	+ 6	− 7	+ 3	" 334
F	19 series	Talcott method	1890–97	0	241 2646	+ 8	0	0	− 26	− 14	Present paper

The testimony of the observations as to the variability of the period is conveniently presented in the following statement, which gives six normal epochs, formed as indicated by the letters in the first column of the foregoing table. The differences of these, taken two and two, give the observed periods. The deviations from the various hypotheses follow in the various columns O—C.

			Period (d)	O—C I	O—C II	O—C III	O—C IV	O—C V
A	238 9521	$B-A$	418.5	−4.8	−16.2	−9.7	−13.0	−12.6
B	239 4115	$C-B$	433.1	+1.4	+ 1.1	+4.9	+ 1.6	+ 2.0
C	240 4076	$D-B$	432.0	+0.1	+ 0.5	+3.8	+ 0.5	+ 0.9
D	240 7075	$E-C$	429.1	−1.2	0.0	+0.9	− 2.4	− 2.0
E	241 0083	$F-D$	428.5	+2.0	+ 0.4	+0.3	− 3.0	− 2.6
F	241 2646	$F-E$	427.2	+2.7	− 0.3	−1.0	− 4.3	− 3.9

My conclusions from the facts presented, which comprise substantially all the competent testimony available, are: (*a*) that the velocity of rotation in the 14-months period is not uniform; (*b*) that the mean period within the interval of precise observation, or since 1825, is 428 days within a small fraction of a day; (*c*) that the hypothesis that the mean period since 1860 can be as great as 431 days is untenable; (*d*) that the hypothesis of a change in the period uniform with the time, while it accords with observations since 1860, is incompatible with those anterior; (*e*) that a change *per saltum* between 1830 and 1860 is also incompatible with the facts, to reconcile all of which requires the assumption of a periodical or at least a continuous one, such as I adopted for empirical representation of the data, five years ago. I do not see how these inferences can be controverted without unduly discrediting the competent results of observations. If any of them conflict with the present state of dynamical theory, that is a matter of concern for the latter, calling for its amendment — and affords another illustration of its blindness as a guide to correct conclusions as to the movement of the actual earth, however obedient to it the imaginary earth of theory may be.

From what foregoes I decided to adopt, for the study of the series 1890–97 under examination, the period 427.0 days, which corresponds to the daily angular velocity $\theta = 0°.843$. With this and preliminary values of r_1 and T_1, x_1 and y_1 were found by eq. (25) *A.J.* 406, and subtracted from the observed values of x and y; giving x_2, y_2, which were then investigated to find the constants in eq. (7). The resulting computed values of x_2, y_2, were then in turn subtracted from the observed x, y, and r_1 and T_1 found anew; and so on until three approximations had been made, the last being adopted as final. For the 14-month term we thus obtain:—

E	Observed T_1	O—C	Observed r_1 (″)	O—C (″)
−3	241 1363	− 3	0.179	+0.010
−2	1788	− 3	.149	− .013
−1	2222	+ 8	.155	.000
0	2651	+13	.145	− .003
+1	3060	0	.138	− .003
+2	3503	+20	.125	− .009
+3	241 3946	+40	0.103	−0.024

The last value is uncertain, being found from an incomplete cycle. The solution for the whole series gave, as the mean values (1890–97.5),

$$T_1 = 241\,2646 \quad , \quad r_1 = 0''.148$$

* The memoir last referred to did not arrive until the present article was written, but I interpolate this statement with regard to it in order to enable astronomers to decide as to the justness of the views therein set forth. Both of the gentlemen of the Leyden Observatory strenuously maintain that the mean period is more than 431 days, and that it is invariable. The formula V is deduced by a peculiar and arbitrary treatment of the results of observation, its initial epoch being based on the Leyden observations alone, on the alleged ground that its errors are far smaller than those of all other series, which are rejected. I must, however, deny the propriety of assigning a weight of zero, relative to Leyden, to the extensive and precise series at Pulkowa between 1863 and 1882, with the Vertical Circle and Prime Vertical Transit.

The differences O−C are from the numerical theory of *A.J.* 322, which gives, for the mean epoch,

$$T_1 = 2412638^{\text{d}}, \quad r_1 = 0''.156$$

with a period $423^{\text{d}}.1$ The above residuals give a correction of about $+5^{\text{d}}$; thus the observed period is 428 days; but this is quite uncertain, depending on the correctness of the involved assumption that the annual period is exactly a year. The observed values of r_1 show a decided diminution during the series. I believe this result to be real, as it is in no way constrained by the assumptions as to the constancy of the annual term. The suspicion might arise that the diminution may be a refluent effect coming through a change of some sort in the annual ellipse, reflected, by the process of elimination, as an apparent change merely, in the dimensions of the 14-months circle. But this does not seem to be so. While an erroneous assumption as to the period of either component will prejudice the epoch and the form of the other, and in the case of the ellipse the direction of its axes, the mean dimensions will be unaltered. By special computations to test the matter I have satisfied myself that the phenomenon of decrease actually pertains to the radius of the circular motion and not to the annual ellipse. Its conformity with the empirical law derived from the observations of 1825–90 is quite striking.

The elements of the annual ellipse given by the investigation are: —

T	L	ω	a	b
	°	°	″	″
1890 Mar. 29	7	43	0.27	0.13
1892 Apr. 3	13	48	0.32	0.08
1893 Mar. 31	9	40	0.26	0.09
1894 Apr. 10	19	48	0.26	0.08
1895 Mar. 29	7	30	0.30	0.09
1896 Apr. 13	23	37	0.27	0.07
1897 Apr. 25	34	26	0.33	0.11
1890–93 Apr. 4	13	45	0.28	0.09
1894–97 Apr. 14	23	35	0.27	0.08
All Apr. 8	17.1	39.6	0.275	0.085

The values found in 1894 (*A.J.* 329) from observations 1890–93 were

1890–93 Apr. 6 15° 45° 0″.30 0″.08

the differences of which from the present calculation for the same interval are merely nominal.

The values of the dimensions of the ellipse for the separate years do not sensibly differ from the mean value. A tendency is noticeable to progression in the elements pertaining to the epoch and the position of the major axis, but not large enough to pronounce as to its reality, considering the delicacy of the problem; and we must await further observations before deciding the question. Nevertheless, without overpressing the interpretation of the results so far obtained, it is important to remember that collateral evidence is at hand that a change of some sort in the position of the annual ellipse must be in progress, without distinctly indicating the character of such change. But we have some light on the problem. Referring to the values of the epoch G for the Greenwich meridian, for the interval 1825–90, in the table on p. 73, *A.J.* 329, and to the chart there accompanying, where its values are represented, on the lower portion, by small circles, it is apparent that they fall into a well-marked curve, which I have there empirically represented by the formula

$$\left.\begin{aligned} G &= 317^\circ - 44^\circ \cos (t - 1865.25)\,.\,5^\circ.48 \\ &\text{and the amplitude by} \\ r_2 &= 0''.135 - 0''.02 \cos (t - 1865.25)\,.\,5^\circ.48 \end{aligned}\right\} \quad (A)$$

It may be incidentally noted that the present investigation furnishes another value for 1891, $G = 363^\circ$, which also falls well on the line of the curve.

Now if we put $\lambda = 0$ in eq. (32), *A.J.* 406, then by eq. (31) and (6) we have for the Greenwich meridian,

$$r_2 \sin G' = \frac{a}{2} \cos \omega \sin L - \frac{b}{2} \sin \omega \cos L$$

$$r_2 \cos G' = \frac{a}{2} \cos \omega \cos L + \frac{b}{2} \sin \omega \sin L$$

whence we get

$$\left.\begin{aligned} \tan (L - G') &= \frac{b}{a} \tan \omega \\ r_2 &= \tfrac{1}{2} \sqrt{[a^2 \cos^2 (L - G') + b^2 \sin^2 (L - G')]} \end{aligned}\right\} \quad (B)$$

The constant G' is the longitude of the sun on the date of minimum latitude, and in these formulas corresponds to the Greenwich meridian. It will be a constant so long as the pole returns to the major axis exactly in a year, in other words, so long as the longitude of the epoch L is a constant, and if the ratio of the axes and their angle to the Greenwich meridian are also constant. If we assume an apsidal motion we get by (B),

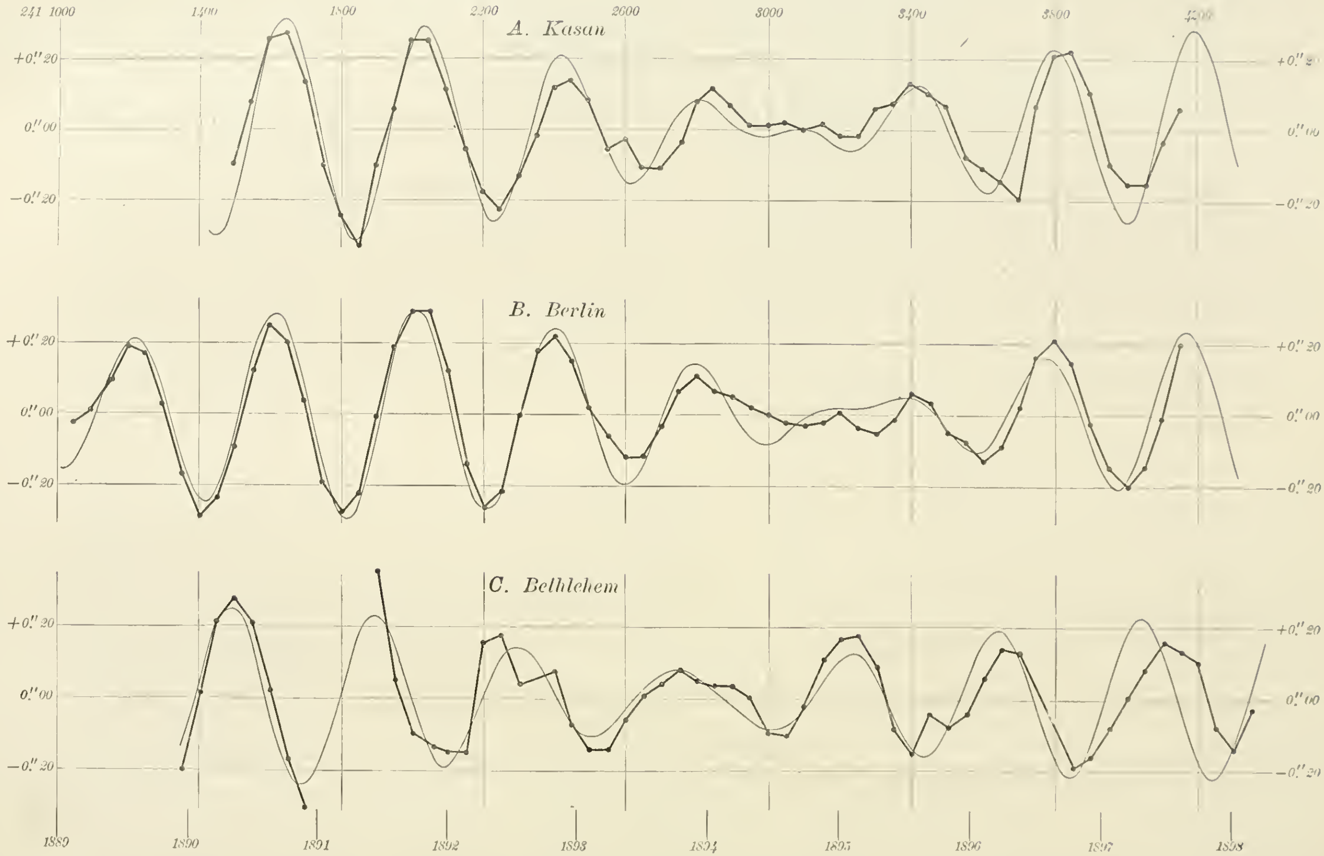
when	$\omega = 0^\circ$	$G = 375^\circ$	$r_2 = 0''.150$
when	$\omega = 90$	$G = 285$	$r_2 = 0.040$

Now it is curious that by the formula of observation (A) the limiting values are

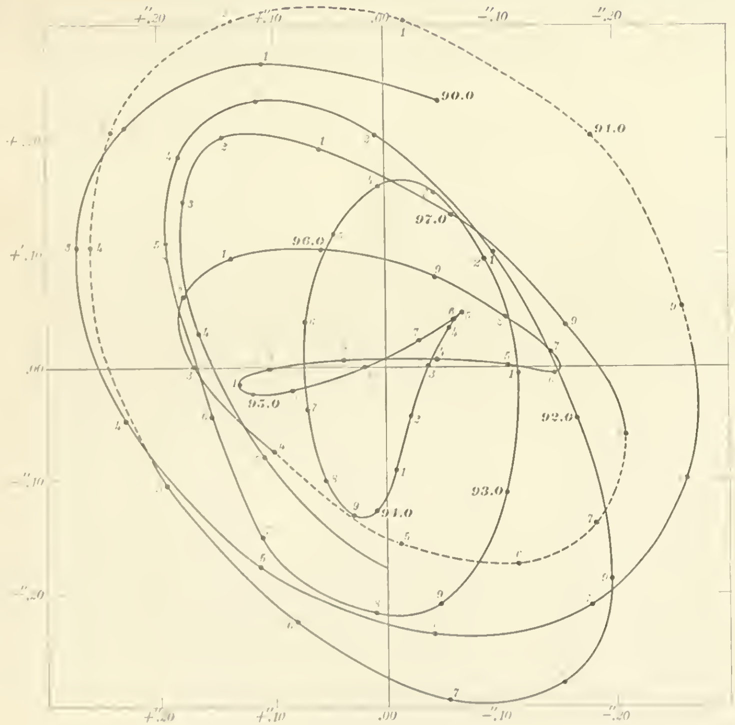
for 1832 and 1899	$G = 361^\circ$	$r_2 = 0''.155$
for 1865	$G = 273$	$r_2 = 0.110$

By comparing the above relations it will be seen that the observed change could be accounted for, on the hypothesis of apsidal motion, by an oscillatory movement of the apses from west to east from 1832 to 1865, and a retrogression from 1865 to 1900, through an angle of about 90°, *i.e.*, from about $\omega = 0$ to $\omega = 90^\circ$ and back again. Further, in the above table of observed elements of the annual ellipse between 1890 and 1897, the apparently indicated change in ω, toward the Greenwich meridian, from about 45° to 30° in this interval, corresponds to a continu-

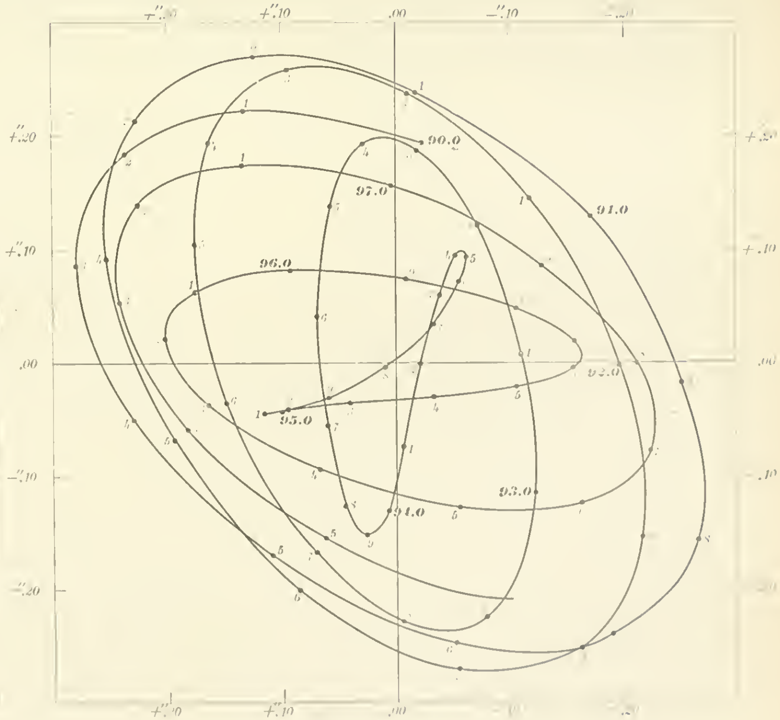
VARIATIONS OF LATITUDE, referred to three normal meridians.



TRAJECTORY OF THE POLE.



ADJUSTED FROM OBSERVATION



PREDICTED BY THEORY

ation of the same motion as that above indicated as taking place by the observations before 1890, on the assumption of apsidal motion. In other words the observations before 1890 would assign, by (A), the values of G for 1890 and 1897.5, as 348° and 361°, respectively; which by (B) would give for 1890 and 1897.5, the angle $\omega = 61°$ and $43°$; while the actually observed values of ω in the table of elements above would give for those dates, roughly, $\omega = 45°$ and $30°$, respectively.

All this, while crude, lends a certain air of probability to the suggestion that the observed changes may be due to an apsidal motion of the ellipse. A few more years of observation will tell definitely. Meanwhile, for the purposes of computation of latitude-variations we must assume all the elements of the ellipse as constant. We therefore adopt the mean values for the whole interval

$$L = 17\overset{\circ}{.}1 \qquad a = 0\overset{''}{.}275$$
$$\omega = 39.6 \qquad b = 0.085$$

which by eq. (5), (6) and (7) give

$$x_2 = 0\overset{''}{.}095 \sin(\odot - 30\overset{\circ}{8})$$
$$y_2 = 0.110 \cos(\odot - \quad 3)$$

For the 14-months term the mean values for the whole interval give

$$x_1 = 0\overset{''}{.}148 \ \sin(t - 2412646)\ 0\overset{\circ}{.}843$$
$$y_1 = 0.148 \ \cos(t - 2412646)\ 0.843$$

Since, however, the variability of both period and radius of this term seems to be demonstrated, I prefer T_1 and θ coming from II on p. 106, and to use for r_1 the same value as heretofore diminished by the constant, 0''.01. Thus instead of eq. (40), *A.J.* 406, we have as the result of the present discussion

$$x = r_1 \sin(t - T_1)\,\theta + 0\overset{''}{.}095 \sin(\odot - 30\overset{\circ}{8})$$
$$y = r_1 \cos(t - T_1)\,\theta + 0.110 \cos(\odot - \quad 3)$$

where

$$T_1 = 2412646 + 127.0\,E - 0.08\,E^2$$
$$\theta = 0°.843 + 0°.000316\,E$$
$$r_1 = 0''.125 + 0''.05 \sin(2414363 - t)\ .\ 0°.015$$

The epoch for r_1 has been changed, for convenience, from 1865 to 1898 by one-half period of the argument of the function.

Taking the differences of these values of x, y, from those heretofore used we see that the differences are nominal except for the epoch T_1. Thus if we suppose the epoch corrected by

$$\Delta T_1 = +8^{d} + 1^{d}.8\,E$$

the remaining differences are, nearly,

$$\Delta x = -0\overset{''}{.}010 \sin(t - T_1)\,\theta + 0\overset{''}{.}008 \sin(\odot - 29\overset{\circ}{4})$$
$$\Delta y = -0.010 \cos(t - T_1)\,\theta + 0.005 \cos(\odot - \quad 0)$$

If we ignore these, the tables for the coordinates and latitude-variations, for 1893–98 published in *A.J.* 360, 392 and 426, may still be used by entering them with the argument of the observed date diminished by

8 days in 1893	13 days in 1896
10 " " 1894	15 " " 1897
12 " " 1895	17 " " 1898

The values of x, y or $\varphi - \varphi_0$ thus found will generally not differ more than 0''.01, never more than 0''.02, from the revised formulas; differences which are within the uncertainty of the determination.

A comparison of these revised elements with the observed values of x, y, on which they are founded give the following deviations, O−C, expressed in hundredths of seconds.

1350 to 1800		1850 to 2300		2350 to 2800		2850 to 3300		3350 to 3800		3850 to 4150	
Δx	Δy	Δx	Δy	Δx	Δy	Δx	Δy	Δx	Δy	Δx	Δy
−2	+6	(+3)	−1	+2	0	−1	−1	−3	+5	0	−2
+1	+5	+1	−4	+1	0	0	−3	−1	+4	−1	−2
+2	+3	−1	−4	−1	0	0	−4	+1	+2	−2	0
+1	0	−2	−4	0	0	0	−3	+1	+1	−3	+3
0	+1	0	−3	0	−1	0	−1	−1	0	−4	+6
−1	0	+3	+2	0	−2	+1	−1	−1	0	−2	+5
−2	+5	+4	−2	0	−2	+3	−1	−2	0	+4	+3
−1	+8	+4	−2	+1	0	+2	−1	0	0	.	.
(+1)	+3	+3	−1	0	0	+1	+1	(0)	−2	.	.
(+3)	+2	+3	−1	0	0	−2	+4	(+2)	−2	.	.

The square-root of the mean square is ±0''.018 for Δx. and ±0''.028 for Δy. The mean deviation in distance between an observed and computed point of the curve is ±0''.034.

The deviations in this table, although small, have a systematic character, which is due largely to the fact that we have used the mean elements of the annual ellipse, disregarding the progressive difference in the annual values of L and ω. If we assume an annual change of 2°.5 in each, such as the observed values apparently show, we can represent the corresponding differences in x and y approximately by

$$\Delta x = -0\overset{''}{.}005 + 0\overset{''}{.}004\,(t - 1894)\sin\odot - 0\overset{''}{.}007\,(t - 1894)\cos\odot$$
$$\Delta y = -0.005 + 0.007\,(t - 1894)\cos\odot + 0.004\,(t - 1894)\cos\odot$$

If these be subtracted, the deviations of the table are greatly improved, and the mean errors above given are reduced to ±0''.017, ±0''.023 and ±0''.029, respectively. It will be interesting to note whether, during 1898 and 1899, the deviations of observations from the elements conform to these differential expressions. If so it will afford evidence that such a hypothetical alteration of L and ω is still in progress.

In conclusion I beg to make some remarks which have an important bearing on the general nature of the phenomenon we are discussing. It is to be remembered that the computed trajectory of the polar motion, exhibited at the

right on plate II, is not the curve of the revised elements of this paper, which would of course conform much more nearly to the curve of observation on the left hand — but is drawn from the formulas determined five years ago, in which all the constants of the 428-day term were derived from the observations from 1825 to 1890, while the observations of 1890 to 1893 were used only to find the constants of the annual term. This curve is, therefore, in a not improper sense, one of prediction during its whole course, and it is absolutely so from 1894.0 to the present time. This being so it would seem that comparison with the observed curve would lead to the conviction of the truth of the theory. If this demonstration is not close enough to satisfy some who incline naturally towards strong conservatism, and whose minds do not readily open to the admittance of new truth, I trust that they will take the trouble to compute the curve from the revised elements of this paper, which of course satisfy the observed curve much more nearly, and again make the comparison. Should they still remain sceptical, then indeed no further argument would avail. That the demonstration is geometrical rather than dynamical can in no wise affect its force, and whoever desires to await a proof of the theory based on dynamical principles must, it is feared, wait a long time. Assuming it to be granted, then, that the earth's axis is subject to a composite motion arising from a uniform circular revolution in 428 days, and a very eccentric central elliptic motion obeying the law of proportionality of times to areas about a mean position on the earth's surface — the important question arises whether it follows this law exactly or only approximately. As to this it is to be remarked that, since the theory, as above shown, represents observation within $\pm 0''.03$ — a quantity that includes accidental as well as probable systematic errors of observation, and also errors in the numerical constants adopted in the application of the theory — the theory can be accepted as exact within the limits of possibilities of observation. Further than this legitimate inference cannot go, and any assumption that it is not literally exact is purely gratuitous, having no greater force than the contrary presumption, in view of our absolute ignorance of the operation of the forces that control the phenomenon.

This juncture is as fitting an opportunity as will perhaps present itself for a remark which circumstances seem to require. The geometrical theory we are discussing has been frequently described as empirical. So far as by this is merely meant that it rests directly on the experience of observation, and is not a deduction from principles, the description is perfectly correct and unobjectionable. But if the stigma that commonly attaches to the word empirical is also here implied, the reproach loses its significance when we consider what manner of principles this "empirical" theory disregards. The rigid, homogeneous globe that so long stood as the basis of the orthodox theory — a stumbling-block in the path — has been swept away by the inexorable logic of fact, and theory is now fumbling for a new set of hypotheses on which to erect a better structure. Theory, being but a mechanical interpretation of assumed conditions, is, in its present state, merely a formulation of our ignorance of real conditions — empiricism organized into a system. In this pass, what does common-sense suggest? Obviously a geometrical theory correctly reared on the facts of observation. This is what I have tried to construct, and, in view of the outcome, I see no less reason now than when I began these investigations eight years ago to ignore all dynamical ideas as to the earth's rotation, as a false beacon that is liable to wreck inquiries as to the truth, as it had done up to that time; nor any reason to be deterred by the slur of empiricism from clinging to the rule then adopted of following implicitly the guide of the observations, regardless where they lead, no matter what conclusions may be encountered, drawn from dynamics, whose canons may rule the imaginary earth of its theory, yet be ruthlessly disobeyed, as they have heretofore been, by the actual one.

ELEMENTS AND EPHEMERIS OF COMET *h* 1898 (PERRINE),

By C. D. PERRINE.

Using the Mount Hamilton observations of September 12, 17 and 22, I derive the following system of elements:

$$T = 1898 \text{ October } 20.53478 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 162^\circ\ 26'\ \ 8''.3 \\ \Omega &= \ \ 34\ \ 55\ \ 37.5 \\ i &= \ \ 28\ \ 51\ \ 27.2 \end{aligned}\right\} 1898.0$$

$$\log q = 9.622688$$

Residuals (O — C).

$$\Delta\lambda' \cos\beta' = +0''.4 \qquad \Delta\beta' = -1''.0$$

CONSTANTS FOR THE EQUATOR OF 1898.0.

$$x = r\,[9.982752] \sin (283^\circ\ 53'\ \ 7''.9 + v)$$
$$y = r\,[9.846710] \sin (210\ \ 48\ \ 53\ .4 + v)$$
$$z = r\,[9.882722] \sin (179\ \ 48\ \ 12\ .1 + v)$$

Ephemeris for Greenwich Midnight.

1898	True α	True δ	log Δ	Br.
	h m s	° ′		
Apr. 30.5	11 26 39	+18 0.3	0.142	2.96
Oct. 2.5	39 38	15 53.7		
4.5	11 52 38	13 40.2	0.138	3.70
6.5	12 5 37	11 19.7		
8.5	18 36	8 52.8	0.138	4.68
10.5	31 35	6 19.9		
12.5	44 35	3 41.4	0.140	5.76
14.5	12 57 37	+ 0 58.7		
16.5	13 10 41	− 1 47.6	0.144	6.66
18.5	23 49	4 35.9		
20.5	37 1	7 24.6	0.149	6.93
22.5	13 50 17	10 11.9		
24.5	14 3 38	12 56.0	0.154	6.37
26.5	17 3	15 34.9		
28.5	30 33	18 7.7	0.159	5.28
30.5	44 7	20 32.9		
Nov. 1.5	14 57 46	22 49.7	0.166	4.13
3.5	15 11 30	24 57.7		
5.5	25 18	26 56.8	0.173	3.16
7.5	39 9	28 46.5		
9.5	15 53 3	30 27.0	0.183	2.41
11.5	16 6 56	31 58.0		
13.5	20 49	33 19.9	0.194	1.85
15.5	34 38	34 33.0		
17.5	16 48 22	35 37.5	0.210	1.42
19.5	17 1 57	36 33.9		
21.5	15 21	37 22.4	0.221	1.13
23.5	17 28 32	−38 3.5		
Nov. 25.5	17 41 29	−38 37.8	0.236	0.89
27.5	17 54 9	39 5.6		
29.5	18 6 30	−39 27.5	0.252	0.71

Brightness at discovery = 1.0.

The comet passes the sun in α on October 22, and becomes an evening object. Owing to its brightness, the comet should be visible in considerable dawn before conjunction, and should again become visible to southern observers about the first of November.

Owing to its close proximity to *Mercury* for some days near the comet's perihelion, it will be desirable to obtain a good series of observations in November.

On October 28, *Mercury* and the comet will have the same longitude and distance from the sun, but owing to a difference of latitude of 8°.2 will be about six million miles apart in absolute distance. For a week or more the two bodies will be within six or eight million miles of each other.

The comet has increased rapidly in brightness since discovery. It is now just visible to the naked eye, and the tail is much more distinct. A nucleus has developed, and is now about 9th magnitude. Although sharp and well defined, it is not quite stellar.

Lick Observatory, University of California, 1898 *September* 27.

OBSERVATIONS OF ASTEROID *DQ*,

MADE AT THE SAYRE OBSERVATORY, SOUTH BETHLEHEM, PA.,

By JOHN H. OGBURN.

1898 Bethlehem M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's Apparent α	Planet's Apparent δ	log Δp for α	log Δp for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Sept. 6	9 5 9	1	7 , 5	−1 8.97	+5 43.2	20 48 57.98	−6 19 23.6	n8.884	0.808
8	8 23 0	2	15 , 9	+0 1.65	−1 17.4	20 46 43.24	−6 19 55.6	n9.109	0.802
10	8 13 14	3	9 , 5	−0 37.85	−5 11.5	20 44 38.85	−6 20 24.2	n9.139	0.806
11	8 33 57	4	10	+0 50.31	+2 55.8	20 43 40.35	−6 20 38.2	n8.948	0.807
12	8 34 50	4	14 , 6	−0 4.12	+2 44.2	20 42 45.91	−6 20 49.8	n8.890	0.808
13	8 30 23	5	12 , 6	+0 35.08	−0 9.2	20 41 55.11	−6 21 3.9	n8.887	0.808
16	8 58 37	6	8 , 5	+1 6.55	−2 26.5	20 39 39.80	−6 21 26.0	7.904	0.806
17	8 4 12	6	9 , 6	+0 30.03	−2 30.9	20 39 3.27	−6 21 30.4	n8.895	0.807
18	7 55 15	6	16 , 5	−0 4.61	−2 28.7	20 38 28.62	−6 21 28.2	n8.993	0.806

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 50 2.59	+4.36	−6 25 25.3	+18.5	⅓ (Munich 1+2 Munich II.)
2	20 46 37.25	+4.34	−6 18 56.5	+18.3	⅓ (Munich 1+2 Munich II.)
3	20 45 12.37	+4.33	−6 15 30.7	+18.0	⅓ (Munich 1+2 Munich II.)
4	20 42 45.72	+4.32	−6 23 52.0	+18.0	Munich II, 10832
5	20 41 15.74	+4.29	−6 21 12.6	+17.9	Munich I, 25949
6	20 38 29.01	+4.23	−6 19 17.2	+17.7	Munich I, 25746

OBSERVATIONS OF COMET *h* 1898 (PERRINE),

MADE AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA, WITH THE 12-INCH EQUATORIAL,

BY C. D. PERRINE.

1898 Mt. Hamilton M.T.	*	No. Comp.	☌ − * Δα	☌ − * Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
Sept. 12 16 51 33	1	8 , 6	+0 56.54	−7 30.0	9 35 49.27	+31 4 31.0	n9.730	0.583
13 16 14 22	2	12 , 8	+4 55.73	+0 58.2	9 41 43.81	+30 35 19.2	n9.736	0.644
14 15 20 5	3	d10 , 8	+0 6.57	−1 32.8	9 47 36.85	+30 4 56.7	n9.724	0.732

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	9 34 50.26	+2.47	+31 12 13.5	−12.5	Leyden A.G. Zones 17 and 286
2	9 36 45.64	+2.47	+30 34 33.6	−12.6	½ (Leyden A.G. Zones 17 and 172 + Brus. 4056)
3	9 47 27.86	+2.42	+30 6 42.4	−12.9	Leyden A.G. Zone 41

NOTES.

The head of the comet is round, about 5′ in diameter and has a bright condensation at the center, but I have seen no stellar point in it. The brightness of the head is about equal to that of an 8th magnitude star. A slender, faint tail can be traced with the 12-inch equatorial for about ¼°, in position-angle 306°.8. *d* indicates that Δα was measured with the micrometer.

Lick Observatory, University of California, 1898 *Sept.* 15.

NEW ASTEROIDS.*

Prof. KREUTZ communicates the discovery of three new asteroids, at Heidelberg; the first by WOLF, and the second and third by WOLF and SCHWASSMANN.

	M	h m		h m s	° ′		
DR	11.0	1898 Sept. 11 11 19.0	Kön.-Heid. M.T.	α = 23 47 28	δ = +0 21	Daily motion −36s, southward 24′	
DS	11.0	11 11 19.0	" " "	23 43 4	−3 51	" " −36s, southward 4′	
DT	12.0	13 10 10.0	" " "	23 53 44	+1 48		
"	"	15 10 44.0	" " "	23 51 48	+1 47		

EPHEMERIS OF ASTEROID *DQ*,*

BY A. BERBERICH (Supp. to *A.N.* 3520). For Berlin Midnight.

1898	α	δ	log r	log Δ
	h m s	° ′		
Oct. 8.5	20 37 15	−6 7.0		
10.5	38 9	6 3.7		
12.5	39 13	6 0.0	0.2203	0.0103
14.5	40 27	5 55.8		
16.5	41 50	5 51.2		
18.5	43 22	5 46.1		
20.5	45 2	5 40.6	0.2153	0.0351
22.5	20 46 51	−5 34.6		
Oct. 24.5	20 48 48	−5 28.0		
26.5	50 53	5 21.0		
28.5	53 5	5 13.5	0.2100	0.0586
30.5	55 24	5 5.5		
Nov. 1.5	20 57 50	4 56.9		
3.5	21 0 22	4 47.8		
5.5	3 1	4 38.3	0.2043	0.0805
7.5	21 5 46	−4 28.2		

VARIATION IN THE *ANDROMEDA*-NEBULA.*

Mr. RITCHIE communicates a dispatch from Dr. KREUTZ, of Sept. 20, as follows: "SERAPHIMOFF (Pulkowa) confirms a stellar condensation in the center of the Nebula in *Andromeda*."

* *From Astronomical Journal*, No. 445.

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MICROMETRICAL MEASURES OF DOUBLE STARS,

MADE AT THE LICK OBSERVATORY,

By E. E. BARNARD.

The following measures of double stars were made with the 36-inch at the request of Mr. BURNHAM. Several of the stars were also observed at the request of Dr. SEE.

In several cases, the star has been observed on one night only. It has been thought best to print these, though it is to be regretted that more observations were not obtained of them.

In several cases it has been possible to measure the angle when the distance could not be measured. This is indicated by a blank in the distance column.

No magnitudes have been assigned to the known stars.

The position of the stars refer to the epoch 1880, which is that employed by Mr. BURNHAM in all his work.

β 232.

$\alpha = 0^h\,43^m\,38^s$; $\delta = +49°\,59'$

A and *B*

	°	″
1892.845	319.7	0.62

γ *Cassiopeae* = β 1028.

$\alpha = 0^h\,48^m\,50^s$; $\delta = +60°\,1'$

A and *B*

1894.763	254.2	2.04
.766	252.7	2.24
.802	254.2	2.38
1894.78	253.7	2.22

β 1099 = B.A.C. 255.

$\alpha = 0^h\,49^m\,33^s$; $\delta = +59°\,43'$

1894.706	291.8	. .
.711	290.6	0.10
.725	288.1	0.09
.763	287.3	0.08
1894.72	289.5	0.09

ϕ *Andromedae.* = $O\Sigma$ 515.

$\alpha = 1^h\,2^m\,30^s$; $\delta = +46°\,36'$

1894.633	61.4	0.16
.882	63.4	0.22
1894.76	62.4	0.19

Very difficult.

DM. 3°184 (New).

$\alpha = 1^h\,12^m\,40^s$; $\delta = +4°\,1'$

1894.556	10.9	1.36

This is a new pair found while observing *Mars*. It is given as $8^M.3$ in DM.

$O\Sigma$ 31.

$\alpha = 1^h\,26^m\,59^s$; $\delta = +7°\,36'$

	°	″
1894.840	79.4	4.23
.843	79.2	4.08
1894.84	79.3	4.15

48 *Cassiopeae* = β 513.

$\alpha = 1^h\,52^m\,7^s$; $\delta = +70°\,19'$

1893.000	316.6	0.65
.942	327.8	0.66
1893.47	322.2	0.65

γ *Andromedae* = $O\Sigma$ 38.

$\alpha = 1^h\,56^m\,32^s$; $\delta = +41°\,45'$

B and *C*

1893.709	124.0	0.15
.824	122.8	0.10
.942	118.5	0.16
1893.82	121.8	0.14
1894.553	122.8	0.14
.556	121.5	0.14
.573	120.4	0.17
1894.56	121.6	0.15
1895.556	117.1	0.16
.589	120.1	0.18
.592	117.6	0.20
.608	117.6	0.21
.744	120.4	0.17
1895.62	118.6	0.18

The small star was noted to be south following.

— *Arietis*, 307, = β 306.

$\alpha = 2^h\,36^m\,52^s$; $\delta = +25°\,8'$

	°	″
1892.840	18.5	3.10
.845	19.2	3.10
.859	18.9	3.12
1892.85	18.9	3.11

20 *Persei* = β 520.

$\alpha = 2^h\,46^m\,9^s$; $\delta = +37°\,51'$

A and *B*

1893.058*

1895.703 77°.9 less than 0″.10

.744†

* Possibly elongated preceding and following.

† Elongation uncertain.

$O\Sigma$ 62.

$\alpha = 3^h\,38^m\,10^s$; $\delta = +64°\,23'$

1895.668	100.2	0.24
.671	101.1	0.24
1895.67	100.6	0.24

β 536.

$\alpha = 3^h\,39^m\,8^s$; $\delta = +23°\,49'$

1892 and 1893 examined carefully. No elongation, especially 1893 Sept. 17, when with first-class seeing and certainly identified it was perfectly round with the highest powers.

α *Tauri* = β 1031.

$\alpha = 4^h\,29^m\,2^s$; $\delta = +16°\,16'$

C and *D*

	°	″
1892.802	276.0	2.15
.807	279.5	2.10
.824	277.9	2.09
1892.82	277.8	2.11

β 883.

$\alpha = 4^h\,44^m\,33^s$; $\delta = +10°\,52'$

A and *B*

1894.649	173.5	0.20
.668	176.8	0.20
.671	178.7	0.16
1894.66	176.3	0.19

β 552.

$\alpha = 4^h\,45^m\,3^s$; $\delta = +13°\,27'$

1894.879	179.9	0.37
.882	174.2	0.44
1894.88	177.0	0.40

26 *Aurigae* = β 1240.

$\alpha = 5^h\,30^m\,56^s$; $\delta = +30°\,25'$

A and *B*

1892.824	352.6	0.23
.843	354.2	0.21
.862	355.8	0.23
1892.84	354.2	0.22
1893.942	342.5	0.16

Procyon.

$\alpha = 7^h\,33^m\,1^s$; $\delta = +5°\,32'$

	°	"
1894.151	337.4	54.52
.153	336.9	54.15
.189	337.5	54.33
.192	337.2	54.39
1894.17	337.2	54.35
1894.802	337.5	54.89
.804	337.6	55.13
.807	337.5	55.14
1894.80	337.5	55.05

9 *Argus* = β 101.

$\alpha = 7^h\,46^m\,13^s$; $\delta = -13°\,35'$

1893.920	278.9	0.52
.939	285.8	0.40
.961	281.6	0.40
1894.153	282.8	0.37
.189	280.8	0.48
.192	282.4	0.42
.824	287.5	0.61
.840	288.2	0.64
.843	287.5	. .
.859	289.4	0.57
.862	283.7	0.71
1894.37	284.1	0.51
1895.170	285.0	0.58
.186	286.1	0.53
.225	285.0	0.62
.244	283.5	0.66
.285	287.6	0.54
1895.22	285.4	0.58

β 581.

$\alpha = 7^h\,57^m\,44^s$; $\delta = +12°\,38'$

1893.920*	85.2	. .
.945†	86.9	0.55
1893.93	86.0	0.55

* Seeing very bad.
† Seeing very fine.

On December 3, there is a note, "A very faint nebula 3′ ±preceding."

ζ Cancri and β 1243.

$\alpha = 8^h\,5^m\,20^s$; $\delta = +18°\,1'$

Difference of Declination.

1894.151	103.78
.153	103.93
.189	103.87
.192	103.80
1894.17	103.845
1895.093	103.84
.096	104.00
.128	103.77
1895.10	103.870

These measures are corrected for refraction.

β 1243 is north following.

β 1243.

$\alpha = 8^h\,7^m\,19^s$; $\delta = +18°\,2'$

	°	"
1894.151	342.8	1.40
.153	343.7	1.36
1894.15	343.2	1.38

o Ursae Majoris = β 1067.

$\alpha = 8^h\,20^m\,17^s$; $\delta = +61°\,7'$

1895.093	195.5	7.27
096	193.3	7.03
1895.09	194.4	7.15

The companion has the same proper motion as the large star.

ω Leonis = Σ 1356.

$\alpha = 9^h\,22^m\,2^s$; $\delta = +9°\,35'$

1894.862	106.9	0.94
.879	107.1	0.94
.882	108.2	0.96
1894.87	107.4	0.95

α Ursae Majoris = β 1077.

$\alpha = 10^h\,56^m\,19^s$, $\delta = +62°\,24'$

1893.055	310.2	1.10
.928	307.7	0.97
1893.49	308.9	1.03

OΣ 234.

$\alpha = 11^h\,24^m\,20^s$; $\delta = +41°\,57'$

1894.821	120.8	0.20
.824	121.0	0.19
.840	123.4	0.24
1894.83	121.7	0.21

β 603 = B.A.C. 3992.

$\alpha = 11^h\,42^m\,28^s$; $\delta = +14°\,57'$

1894.843	324.3	1.27
.859	325.1	1.05
1894.85	324.7	1.16

Σ 3123.

$\alpha = 12^h\,0^m\,0^s$; $\delta = +69°\,22'$

A and *B*

1895.093	5.6	0.26
.096	13.6	0.30
.131	13.7	0.35
.170	14.6	0.35
.186	14.9	0.28
.225	11.8	0.25
1895.15	12.2	0.30

A B and *C* (new star)

1895.096	312.8	2.91
.148	310.5	2.78
.170	312.8	2.94
1895.10	312.0	2.88

The star *C* was discovered February 5, 1895. It is about 16M.

OΣ 256.

$\alpha = 12^h\,50^m\,17^s$; $\delta = -0°\,18'$

	°	"
1894.879	72.3	1.05
.882	68.6	0.83
1894.88	70.4	0.94

DM. 16°2448 (New).

$\alpha = 12^h\,56^m\,31^s$; $\delta = +16°\,12'$

	°	"	M	M
1895.302	41.3	2.97	9.5	9.5

25 *Canum Venat.* = Σ 1768.

$\alpha = 13^h\,32^m\,7^s$; $\delta = +36°\,54'$

1895.093	132.5	1.39
.096	133.3	1.26
.131	131.9	1.40
.170	135.5	1.06
.186	136.6	0.97
.225	130.3	1.22
.266	128.0	1.34
.285	132.3	1.03
1895.18	132.5	1.18

β 612.

$\alpha = 13^h\,33^m\,40^s$; $\delta = +11°\,21'$

1894.057	202.9	0.33
.074	202.8	0.28
.153	207.6	0.30
.189	208.8	0.39
1894.12	207.4	0.32

γ Coronae Borealis = Σ 1967.

$\alpha = 15^h\,37^m\,42^s$; $\delta = +26°\,41'$

1894.534	122.2	. .
.553	122.6	0.56
.573	121.2	0.63
.575	120.1	0.63
.592	120.3	0.59
1895.473	122.3	0.66
.608	118.1	0.54
.666	127.0	0.75
.668	124.5	0.59
1895.03	122.0	0.62

ε Coronae Borealis = A.G.C. 7

$\alpha = 15^h\,52^m\,37^s$; $\delta = +27°\,14'$

1895.666	350.2	1.91
.668	349.5	2.01
1895.67	349.8	1.96

ζ Herculis = Σ 2084.

$\alpha = 16^h\,36^m\,47^s$; $\delta = +31°\,49'$

1894.496	47.2	1.28
.499	42.7	1.30
.515	41.6	1.15
1894.50	43.8	1.24

Δ 15.

$\alpha = 16^h\,40^m\,12^s$; $\delta = +43°\,42'$

	°	"
1895.244	339.4	0.63
.266	338.9	0.50
.282	340.6	0.63
1895.26	339.6	0.59

Σ 2106.

$\alpha = 16^h\,45^m\,24^s$; $\delta = +9°\,37'$

1895.302	311.1	0.38
.304	312.0	0.36
1895.30	311.5	0.37

— *Herculis*, 167, = Σ 2107.

$\alpha = 16^h\,47^m\,5^s$; $\delta = +28°\,52'$

1895.329	300.9	. .
.266	301.4	0.35
.282	288.9	0.37
.285	293.8	0.37
1895.29	296.2	0.36

μ Draconis = β 1088.

$\alpha = 17^h\,2^m\,51^s$; $\delta = +54°\,38'$

B and *C*

1895.263	190.7	12.46
.268	191.6	12.22
.304	190.0	12.39
1895.28	190.8	12.36

α Herculis.

$\alpha = 17^h\,9^m\,10^s$; $\delta = +14°\,32'$

A and *B* (Σ 2140)

1895.455	114.6	5.02

A and *C* (A. G. Clark)

1895.455	334.4	23.53

β 416.

$\alpha = 17^h\,10^m\,47^s$; $\delta = -34°\,51'$

A and *B*

1894.307	336.0	1.38
.610	336.5	1.26
.613	334.0	1.27
.633	332.5	1.42
.649	333.6	1.29
1894.56	334.5	1.30

A and *C*

1894.613	129.4	30.01

Σ 2145.

$\alpha = 17^h\,11^m\,47^s$; $\delta = +26°\,43'$

A and *B*

1892.802*	49.9	0.4 ±
.807	50.2	0.40
.838	49.0	0.43
1892.81	49.7	0.41

* Distance estimated.

This star was discovered by H. C. Wilson at Carleton College Observatory with the 16-in. Brashear Refractor.

OΣ 327.

$\alpha = 17^h\ 11^m\ 53^s$; $\delta = +56°\ 16'$

	°	″
1895.342	130.5	0.31
.362	135.1	0.27
1895.35	132.8	0.29

26 *Draconis* = β 962.

$\alpha = 17^h\ 33^m\ 44^s$; $\delta = +61°\ 48'$

1894.189	102.7	0.58

μ *Herculis* = A.C. 7.

$\alpha = 17^h\ 41^m\ 47^s$; $\delta = +27°\ 48'$

B and *C*

1894.189	36.6	1.44
.192	38.3	1.46
.227	38.1	1.51
.269	38.0	1.37
.288	41.6	1.39
.307	39.5	1.03
.323	38.0	1.50
.383	38.8	1.20
.403	40.8	0.73
.479	40.4	1.40
.496	44.8	1.38
.499	42.5	1.38
.515	42.5	1.44
.649	43.4	1.24
1894.37	40.2	1.32

Small Double Star (New) 8ᴹ.5–10ᴹ.

$\alpha = 17^h\ 45^m$; $\delta = +23°\ 50' \pm$

1895.359	239.5	1.26

99 *Herculis* = A.C. 15.

$\alpha = 18^h\ 2^m\ 28^s$; $\delta = +30°\ 33'$

1895.381	310.9	0.97
.416	307.2	1.12
.419	315.9	0.90
.438	308.2	1.18
.458	307.3	1.07
.668	307.7	1.02
1895.46	309.5	1.04

Double Star in Nebula.

$\alpha = 18^h\ 2^m\ 37^s$; $\delta = -24°\ 8'$

A and *B* (New) 10ᴹ–12ᴹ

1894.592	186.3	5.08
.594	183.9	5.10
1894.59	185.1	5.09

A and *C* (H. 5026) 10ᴹ–13ᴹ

1894.592	140.0	34.13
.594	140.0	34.17
1894.59	140.0	34.15

Herschel gives estimated angle of A.C. = 130°±, but no distance or magnitudes, with note. "Coarse double in a neb." There are no other measures.

β 133 8ᴹ.5–8ᴹ.5.

$\alpha = 18^h\ 20^m\ 15^s$; $\delta = -26°\ 42'$

	°	″
1895.458	260.5	2.10

L 34422 (New) 9ᴹ.0–9ᴹ.5.

$\alpha = 18^h\ 29^m\ 47^s$; $\delta = -12°\ 5'$

1895.627	130.6	0.24
.630	132.3	0.25
.666	127.9	0.22
1895.64	130.3	0.24

The magnitude in S.DM. is 8ᴹ.2.

Professor Aitken has measured this star with the 36-inch at L.O. Following are his measures which he has kindly communicated to me.

	°	″	M M
1898.430	120.4	0.34	9.0–9.5
.482	125.3	0.34	8.5–9.5
.506	124.9	0.27	8.5–9.5
1898.473	123.5	0.32	8.7–9.5

There is possibly a slight retrograde motion.

— *Draconis* 205. = β 971.

$\alpha = 18^h\ 44^m\ 24^s$; $\delta = +49°\ 18'$

1894.610*

.613†

* Single.

† Single. Slight suspicion of elongation s.p. Seeing fine. Examined with 520, 1000, 1500 and 2600.

ζ *Sagittarii.*

$\alpha = 18^h\ 55^m\ 0^s$; $\delta = -30°\ 3'$

1895.610	190.3	0.11
.630	196.9	0.15
1895.62	193.6	0.13

H.N. 126 = B.A.C. 6504.

$\alpha = 18^h\ 57^m\ 10^s$; $\delta = -21°\ 43'$

1895.589	332.5	0.37
.592	335.1	0.34
.608	332.4	0.38
.610	331.1	0.31
.627	331.4	0.30
.630	326.8	0.40
1895.61	331.6	0.35

ξ *Aquilae* = β 287.

$\alpha = 18^h\ 59^m\ 54^s$; $\delta = +13°\ 41'$

1891.383	57.0	6.18

β¹ *Capricorni.*

$\alpha = 20^h\ 14^m\ 2^s$; $\delta = -15°\ 10'$

1892.515	100.2	1.15
.518	101.5	1.17
.586*	102.9	. .
1892.687	104.6	1.21

β¹ *Capricorni.* — Cont.

$\alpha = 20^h\ 14^m\ 2^s$; $\delta = -15°\ 10'$

	°	″
1893.652	100.9	1.05
.655	107.3	1.24
.671	102.4	1.19
1894.383†	104.0	. .
.499	100.0	0.84
1893.35	102.6	1.12

* Position-angle with 12-inch.

† Too poorly seen for distance.

This star was discovered by me with the 6-inch of the Vanderbilt University in 1883 through a peculiarity in its disappearance at occultation by the moon.

The only other measures are

1884.59*	105.8	0.85
1886.72†	109.6	0.83
1888.66‡	105.9	0.84
1891.60§	108.0	0.91

* β 3 nights. † Hough 2 nights. ‡ β 4 nights. § β 3 nights.

β *Delphini* = β 151.

$\alpha = 20^h\ 31^m\ 55^s$; $\delta = +14°\ 11'$

A and *B*

1892.865	338.0	0.55
.879	337.3	0.43
1892.87	337.6	0.49
1893.652	340.9	0.49
.655	342.5	0.62
.709	340.8	0.50
.728	344.1	0.59
.766	342.8	0.61
1893.70	342.2	0.56
1894.342	344.4	0.51
.441	347.6	0.70
.499	347.3	0.48
.515	346.9	0.52
.534	343.0	0.68
.537	349.6	0.51
.553	346.2	0.52
.633	345.7	0.57
1894.51	346.3	0.56
1895.342	347.7	0.87
.419	353.8	0.73
.455	348.0	0.84
.473	352.0	0.57
.493	349.9	0.60
.722	347.2	0.49
1895.48	349.7	0.68

4 *Aquarii* = Σ 2729.

$\alpha = 20^h\ 45^m\ 4^s$; $\delta = -6°\ 4'$

1895.473	192.4	0.27
.493	192.1	0.29
.512	194.4	0.32
.515	192.4	0.25
.531	194.7	0.27
.589	191.9	0.27
.610	192.0	0.24
1895.53	192.8	0.27

DM. 3°4467 (New).

$\alpha = 20^h\ 52^m\ 14^s$; $\delta = +3°\ 29'$

	°	″
1891.818	84.2	1.31

Discovered and measured with the 12-inch.

δ *Equulei* = OΣ 535.

$\alpha = 21^h\ 8^m\ 38^s$; $\delta = +9°\ 31'$

A and *B*

1893.862	18.7	0.20
.865	21.5	0.20
1893.86	20.1	0.20

τ *Cygni* = A.G.C. 13.

$\alpha = 21^h\ 10^m\ 0^s$; $\delta = +37°\ 32'$

1894.725	345.5	0.76
.766	339.0	0.77
.782	342.6	1.02
.785	347.0	0.68
.804	347.9	0.67
1894.77	344.4	0.78

β 1140.

$\alpha = 21^h\ 14^m\ 1^s$; $\delta = +58°\ 6'$

1893.788	275.1	4.63
.824	273.2	4.17
1893.80	274.1	4.40

A photograph with the Willard lens, 1893 Oct. 13, shows this star to be involved in rather strong nebulosity.

β 838.

$\alpha = 21^h\ 14^m\ 51^s$; $\delta = +2°\ 37'$

1894.575	101.1	1.82

Σ 2790.

$\alpha = 21^h\ 15^m\ 55^s$; $\delta = +58°\ 7'$

A and *B*

1893.788	42.7	4.39
.824	43.0	4.52
1893.80	42.8	4.45

A and *C* (New) 15ᴹ.

1893.830*	183.1	15.35
1898.722	183.6	15.72
.740	182.9	16.30
1898.73	183.2	16.01

* Single setting of wires.

The last two measures were made with the 40-inch.

24 *Aquarii* = β 1212.

$\alpha = 21^h\ 33^m\ 20^s$; $\delta = -0°\ 36'$

1894.612	265.2	0.54
.654	264.4	0.55
.668	266.4	0.47
.671	261.8	0.48
.689	263.8	0.53
.706	265.5	0.48
1895.744	266.0	0.51
1894.82	264.7	0.52

κ *Pegasi* = β 989.

$\alpha = 21^h\ 39^m\ 12^s$; $\delta = +25°\ 6'$

A and *B*

	°	″
1892.	131.0	0.20
1893.709	131.7	0.23
.824	123.4	0.17
1893.76	127.5	0.20
1894.342	116.9	. .
.499	117.4	0.22
.515	120.0	0.19
.534	117.4	0.16
.537	118.1	0.20
.553	117.0	0.19
.556	116.1	0.19
1894.50	117.6	0.19
1895.433	111.3	0.19
.608	106.6	0.19
.610	105.3	0.18
.647	107.5	0.16
.666	108.3	0.16
.668	107.7	0.18
1895.60	107.8	0.18

A B and *C*

1895.436	300.8	12.13
.438	301.0	12.13
.512	300.6	12.40
.515	300.3	12.21
.649	301.7	12.35
.725	300.8	12.18
.742	302.4	12.48
.744	301.2	12.36
1895.60	301.1	12.28

η *Pegasi* = β 1144.

$\alpha = 22^h\ 37^m\ 23^s$; $\delta = +29°\ 36'$

B and *C*

1893.011	79.3	0.22
.655	83.2	0.31
.731	83.0	0.50
.824	82.9	0.21
.865	82.2	0.31
1894.556	80.4	0.30
.573	82.8	0.48
.575	86.9	0.47
1895.744	80.2	0.20
1894.06	82.3	0.33

β 382 = B.A.C. 7983.

$\alpha = 22^h\ 48^m\ 18^s$; $\delta = +44°\ 7'$

A and *B*

1892.880	220.3	1.00
.884	225.5	0.94
1893.731	225.3	1.10
.766	225.7	1.12
1894.610	225.1	0.93
.613	219.4	0.94

β 382 = B.A.C. 7983.—Cont.

$\alpha = 22^h\ 48^m\ 18^s$; $\delta = +44°\ 7'$

A and *B*

	°	″
1894.630	225.7	1.09
.633	220.9	0.92
1893.97	226.0	1.00

OΣ 536.

$\alpha = 22^h\ 52^m\ 29^s$; $\delta = +8°\ 43'$

1893.728	341.0	0.25
.731	344.5	0.30
.865	350.6	0.22
1893.77	345.4	0.26
1894.862	344.7	0.20
.879	344.5	0.20
.882	347.8	0.23
1894.87	345.7	0.21

2 *Piscium* (New).

$\alpha = 22^h\ 53^m\ 18^s$; $\delta = +0°\ 19'$

1894.594	92.3	3.78
.602	95.2	3.94
.725	95.4	3.77
.785	92.6	3.64
.802	92.9	4.06
1895.668	89.8	4.02
1894.86	93.0	3.87

This star was discovered by me with the 12-inch of Lick Observatory in 1889.

The following observations have been obtained with the 40-inch of the Yerkes Observatory.

1898.662	94.4	3.76
.668	91.0	3.61
.673	93.8	3.51
1898.67	93.1	3.63

Mr. BURNHAM's measures for this object are

1889.57*	93.6	3.81
1891.59†	92.6	3.27

*3 nights. †4 nights.

There seems to be no certain change in the small star, which is 13ᴹ. It has the same proper motion as 2 *Piscium*.

Ψ^1 *Aquarii* = β 1220.

$\alpha = 23^h\ 9^m\ 35^s$; $\delta = -9°\ 44'$

B and *C*

1894.613	102.1	0.20
.649	98.3	0.26
.668	105.0	0.25
.671	90.2	0.34
.706	99.7	0.36
1894.66	99.1	0.28

β 79.

$\alpha = 23^h\ 11^m\ 24^s$; $\delta = -2°\ 10'$

A and *B*

	°	″
1894.649	91.1	1.10
.668	89.9	0.86
.671	91.4	1.10
.706	90.4	0.99
1894.67	90.7	1.01

A and *C* (New) $16\frac{1}{2}^M$

1894.668	157.5	15.95
.671	157.2	16.04
1894.67	157.3	16.00

72 *Pegasi* = β 720.

$\alpha = 23^h\ 28^m\ 0^s$; $\delta = +30°\ 40'$

1893.922	152.7	0.46
1894.359	154.4	0.36
.362	153.6	0.34
.610	154.4	0.36
.613	153.6	0.34
.649	153.6	0.37
1894.42	153.8	0.37

85 *Pegasi* = β 733.

$\alpha = 23^h\ 55^m\ 5^s$; $\delta = +26°\ 27'$

A and *B*

1892.879	165.4	0.73
1893.917	173.6	0.92
.920	172.8	0.96
.942	175.6	0.77
1893.92	174.0	0.88
1894.499	180.3	0.86
.515	177.2	0.80
.534	178.0	0.87
.553	181.7	0.93
.556	175.8	0.75
1894.53	178.6	0.84
1895.473	188.6	0.75
.589	189.1	1.03
.592	191.4	0.83
.608	193.0	0.84
.610	188.9	0.81
.630	186.4	. .
.666	189.9	0.68
.668	191.6	0.87
.703	188.0	0.96
.742	193.7	0.73
.744	194.9	0.77
1895.64	190.5	0.83

The following have been selected from a few double stars found here with the 40-inch, and are given now as possibly being of some interest.

β *Andromedae* 14ᴹ.

$\alpha = 1^h\ 3^m\ 1^s$; $\delta = +34°\ 59'$

	°	″
1897.649	186.1	28.42
.723	186.2	28.40
.726	186.8	28.55
1898.566	185.8	28.31
.569	185.5	28.29
1898.05	186.1	28.39

γ *Andromedae* 15ᴹ.

$\alpha = 1^h\ 56^m\ 32^s$; $\delta = +41°\ 45'$

1898.668	244.4	27.78
.740	244.9	28.10
1898.704	244.6	27.94

Capella 16ᴹ.

$\alpha = 5^h\ 7^m\ 50^s$; $\delta = +45°\ 52'$

1898.610	22.6	. .
.662	23.4	46.92
.665	22.3	46.46
.668	22.3	46.50
1898.51	22.6	46.63

DM. +32°3773 9ᴹ–9ᴹ.5.

$\alpha = 20^h\ 13^m\ 18^s$; $\delta = +32°\ 49'$

A and *B*

1897.682	197.1	0.26
1898.668	201.0	0.25
.670	201.7	0.27
1898.34	199.9	0.26

A B and *C* 13ᴹ

1897.682	257.4	. .
.690	260.8	2.91
.731	257.4	2.93
1898.673	256.7	2.87
.720	257.5	2.64
.722	258.9	2.74
1898.20	258.1	2.82

This star is near and preceding OΣ 405, which was also seen.

Professor AITKEN has secured the following measures with the 36-inch:

A and *B* 8ᴹ.1–8ᴹ.4.

1898.40*	198.4	0.31

A B and *C*

1898.40†	158.4	2.88

*3 Nights. †3 Nights.

Yerkes Observatory, Williams Bay, Wis., 1898 *Sept.* 27.

OBSERVATIONS OF THE SATELLITES OF *SATURN*,

MADE WITH THE 26-INCH REFRACTOR OF THE LEANDER M^{c}CORMICK OBSERVATORY,

By HERBERT R. MORGAN.

The following angles are each the mean of two settings. The distances were obtained from measures of double distances. Corrections have been applied for refraction.

Mimas–Enceladus.

1898	Eastern Time	p	Eastern Time	s
	h m s	°	h m s	″
Aug. 6	8 8 1	136.77	8 16 29	23.77
	8 29 20	144.24	8 21 59	22.43

Mimas–Dione.

1898	Eastern Time	p	Eastern Time	s
Aug. 6	8 42 29	40.07	8 52 53	23.20
	9 5 23	43.01	8 57 39	22.10

Enceladus–Tethys.

1898	Eastern Time	p	Eastern Time	s
Apr. 21	13 11 20	305.89	13 22 28	28.64
	13 36 13	310.36	13 28 28	28.34
June 6	9 45 59	63.35	10 0 27	6.44
	10 11 39	60.70	10 5 14	6.53
11	9 31 12	272.04	9 42 14	8.51
	10 2 17	273.46	9 52 26	8.51
30	11 34 14	333.71	11 39 59	22.15
	11 48 56	337.34	11 44 24	21.92
July 1	11 24 35	110.19	11 31 38	7.88
	11 41 8	107.89	11 35 58	8.17
3	10 3 0	109.80	10 12 47	66.71
	10 24 54	111.36	10 18 37	66.51
25	8 34 54	71.03	. . .	. .
	10 9 0	79.52	10 17 40	42.68
	10 36 10	81.39	10 25 40	42.68
Aug. 1	8 33 27	236.58	8 41 58	27.92
	8 56 22	240.14	8 49 15	28.63
5	8 1 9	302.78	8 13 15	6.34
	8 30 11	303.53	8 19 31	6.38
	8 44 59	301.21	8 56 9	6.08
	9 8 24	302.54	9 0 44	6.25
6	9 22 27	95.00	9 33 53	44.92
	9 45 51	96.43	9 39 17	45.16
8	8 47 56	159.72	8 59 43	34.89
	9 10 31	164.76	9 4 53	34.04
15	8 4 48	80.09	8 10 42	8.38
	8 21 46	79.96	8 14 41	8.10
16	8 4 16	197.77	8 16 43	20.32
	8 34 26	205.93	8 42 6	20.52
22	7 46 6	276.43	7 52 4	69.17
	8 2 8	277.81	7 57 12	68.77

Enceladus–Dione.

1898	Eastern Time	p	Eastern Time	s
Apr. 21	13 47 48	5.09	14 1 30	35.58
	14 22 56	12.99	14 11 33	35.09
June 11	10 18 24	134.59	10 28 32	34.78
	10 46 44	138.42	10 37 6	31.28
30	11 9 36	117.12	11 15 2	33.59
	11 24 46	118.73	11 19 19	33.87
July 3	9 33 30	151.53	9 41 17	28.57
	9 52 37	156.28	9 45 52	28.88

Enceladus–Dione. — Cont.

1898	Eastern Time	p	Eastern Time	s
	h m s	°	h m s	″
Aug. 1	9 8 58	92.67	9 15 10	61.30
	9 25 52	93.61	9 20 20	61.08
5	9 21 55	199.70	9 28 43	27.44
	9 40 31	204.26	9 32 57	27.88
15	8 36 48	114.56	8 43 24	32.48
	8 54 19	115.61	8 48 52	32.01
16	8 52 31	208.30	8 59 21	28.60
	9 15 39	213.57	9 5 49	28.82
22	8 10 4	277.21	8 15 42	82.48
	8 26 9	277.92	8 20 22	82.13

Enceladus–Rhea.

1898	Eastern Time	p	Eastern Time	s
Apr. 21	14 39 26	281.83	14 48 43	52.09
	15 1 30	282.00	14 53 53	51.80
July 1	11 50 8	169.47	11 57 28	21.58
	12 8 15	167.86	12 2 21	21.21
3	9 13 24	311.23	9 19 14	33.11
	9 26 52	311.85	9 22 47	33.19
Aug. 1	9 37 53	106.77	9 44 25	90.72
	9 57 56	107.37	9 51 21	90.13
6	10 24 25	105.64	. . .	. .
15	9 1 8	143.00	9 10 44	42.45
	9 27 52	145.61	9 20 30	41.30
22	8 40 6	294.92	8 51 48	72.85
	9 6 42	296.45	8 57 50	72.55

Tethys–Dione.

1898	Eastern Time	p	Eastern Time	s
Mar. 14	15 12 13	68.43	15 21 48	68.53
	15 46 3	71.13	15 33 53	69.22
25	16 34 11	54.62	16 53 4	60.83
	17 19 19	60.05	17 9 47	62.51
Apr. 12	13 5 38	233.63	13 13 33	55.56
	13 29 21	236.70	13 20 31	56.15
July 25	8 4 54	215.43	8 11 14	48.06
	8 22 30	218.93	8 15 41	48.47
Aug. 3	7 58 51	8.21	8 3 53	13.82
	8 15 29	12.48	8 7 43	13.66
15	9 19 46	130.71	9 55 29	21.78
16	9 31 44	199.37	9 36 45	8.02
	9 47 39	204.11	9 40 19	7.66
22	9 16 36	269.44	9 21 20	14.34
	9 29 20	269.90	9 25 36	15.23

Tethys–Rhea.

1898	Eastern Time	p	Eastern Time	s
July 1	12 20 28	192.07	12 25 53	18.35
	12 35 3	192.54	12 30 11	18.14
30	8 43 58	314.17	8 55 26	39.92
	9 3 40	315.62	8 59 57	39.81

Tethys–Titan.

1898	Eastern Time	p	Eastern Time	s
Mar. 14	16 50 23	320.37	17 4 13	87.59
	17 23 24	320.45	17 13 45	86.39
July 30	9 59 56	210.60	10 5 42	72.50
	10 16 44	210.75	10 9 56	72.77

Tethys–Hyperion.

1898	Eastern Time	p	Eastern Time	s
	h m s	°	h m s	″
June 7	10 52 58	6.85	11 11 26	94.63
	11 31 6	6.48	11 13 10	93.65

Tethys–Iapetus.

July 30	9 35 58	313.20	9 41 26	182.18
	9 50 14	313.70	9 45 4	181.35
Aug. 1	10 20 44	11.84	10 25 40	151.46
	10 34 14	12.23	10 29 51	151.17
3	8 55 24	40.60	9 2 5	163.63
	9 11 29	40.68	9 6 9	163.58

Dione–Rhea.

Mar. 14	15 56 23	136.87	16 9 55	52.62
	16 31 15	139.89	16 18 35	52.52
Apr. 12	12 20 8	289.97	12 30 45	38.68
	12 44 48	289.74	12 37 21	37.69
June 6	10 26 21	6.29	10 36 24	34.19
	10 52 49	11.06	10 42 31	34.09
20	12 48 53	72.77	12 57 15	53.62
	13 9 15	73.60	13 3 30	53.32
Aug. 23	7 53 18	47.26	8 0 28	13.33
	8 12 38	47.94	8 6 19	13.51

Dione–Hyperion.

June 7	10 7 40	330.31	10 19 18	95.54
	10 30 56	329.29	10 20 46	94.35

Dione–Iapetus.

1898	Eastern Time	p	Eastern Time	s
	h m s	°	h m s	″
Aug. 1	7 57 44	337.52	8 3 43	101.14
	8 20 17	337.55	8 10 9	100.76
3	8 25 5	42.33	8 31 50	152.18
	8 43 33	42.30	8 37 47	151.80

Rhea–Titan.

Apr. 12	13 41 43	265.81	13 52 55	102.99
16	12 36 38	7.17	12 46 38	101.30
	13 7 31	9.06	12 51 6	101.20

Rhea–Hyperion.

June 7	9 29 6	317.22	9 37 53	108.35
	9 48 3	316.41	9 39 50	107.85

Rhea–Iapetus.

July 30	9 11 22	349.52	9 16 40	150.07
	9 25 30	349.52	9 20 47	150.22
Aug. 5	9 53 10	37.86	10 2 9	122.38
	10 16 57	37.89	10 8 47	121.88

Titan–Iapetus.

June 6	11 49 44	118.54	12 1 11	197.88
	12 10 47	117.89	12 4 7	197.98
30	11 58 14	263.67	12 4 39	157.40
	12 11 44	263.73	12 6 36	157.77
Aug. 8	8 2 10	79.35	8 9 33	125.03
	8 22 31	79.10	8 17 5	124.68

OBSERVATIONS OF THE SATELLITES OF *SATURN*,

MADE WITH THE 26-INCH REFRACTOR OF THE LEANDER McCORMICK OBSERVATORY,

BY ORMOND STONE.

As in the case of previous observations, the angles given are each the mean of two comparisons; the distances were obtained from measures of double distances. Corrections have been applied for refraction.

Mimas–Tethys.

1896	East. Mean Time	p	East. Mean Time	s
	h m s	°	h m s	″
Mar. 17	15 18 24	228.43	. . .	. .
	15 37 50	233.07	. . .	. .

Mimas–Dione.

Mar. 17	15 17 49	157.97	. . .	. .
	15 38 16	164.57	. . .	. .

Enceladus–Tethys.

Feb. 21	16 46 49	226.08	16 48 36	25.49
Apr. 7	15 44 12	296.51	15 56 42	2.69
	15 49 39	295.68	16 1 2	2.70
	16 18 25	294.33	16 7 34	2.63
	16 24 17	294.58	16 12 8	2.70
May 10	13 2 48	89.63	13 10 32	81.80
	13 19 6	90.52	13 12 42	81.69

Enceladus–Dione.

1896	East. Mean Time	p	East. Mean Time	s
	h m s	°	h m s	″
Feb. 21	17 16 43	194.33	17 16 24	19.86

Enceladus–Rhea.

Mar. 17	16 6 24	183.95	16 13 25	16.84
	16 27 32	179.48	16 15 49	16.66

Tethys–Dione.

Feb. 21	17 36 39	99.51	17 38 46	17.69
Mar. 24	14 45 24	336.37	15 4 15	31.17
	14 50 16	337.88	15 6 2	30.73
	15 25 21	347.29	15 15 25	30.55
	15 29 33	348.70	15 17 19	30.46
Apr. 6	13 51 46	273.73	14 0 7	99.20
	14 8 42	274.31	14 2 5	98.78
15	12 29 3	85.30	12 42 12	37.45
	12 32 45	85.26	12 44 40	37.59
	13 5 7	86.30	12 56 14	36.92
	13 8 51	86.39	12 58 25	36.76
May 10	13 24 43	86.02	13 30 15	12.37
	13 38 36	85.86	13 33 39	12.64

Tethys–Rhea.

1896	East. Mean Time	p	East. Mean Time	s
	h m s	°	h m s	″
Apr. 6	14 19 2	283.19	14 34 23	99.28
	. . .	. .	14 37 25	99.58
15	11 31 40	275.86	11 49 13	48.41
	11 38 26	275.72	11 52 0	48.30
	12 13 18	275.74	12 3 10	49.16
	12 19 20	276.06	12 6 50	49.31
May 10	13 48 12	188.53	13 54 40	27.03
	14 9 3	192.25	13 59 7	26.85

Dione–Rhea.

1896	East. Mean Time	p	East. Mean Time	s
Feb. 23	17 9 28	169.53	17 16 35	36.08
	17 30 32	173.24	17 22 35	35.77
Mar. 24	14 18 45	301.01	14 30 30	20.37
	14 40 34	301.60	14 33 30	20.30
	15 43 34	302.27	15 52 1	21.30
	16 0 49	302.06	15 53 43	21.18
Apr. 6	13 28 56	177.57	13 34 5	15.11
	13 43 46	179.39	13 37 2	14.89
7	16 55 44	191.16	17 4 47	15.31
	16 59 37	190.99	17 8 12	15.51
	. . .	. .	17 13 36	15.48
	. . .	. .	17 17 0	15.77
13	13 6 52	217.09	13 18 18	17.38
	13 12 40	216.27	. . .	. .

Dione–Rhea. — Cont.

1896	East. Mean Time	p	East. Mean Time	s
	h m s	°	h m s	″
May 10	14 15 2	215.03	14 20 30	53.00
	14 29 25	217.82	14 25 26	53.24

Rhea–Titan.

1896	East. Mean Time	p	East. Mean Time	s
Feb. 23	16 24 46	303.99	16 34 48	148.31
	16 44 15	304.52	16 52 10	145.52
	16 58 43	304.84	. . .	. .

Rhea–Hyperion.

1896	East. Mean Time	p	East. Mean Time	s
May 10	11 32 30	113.85	11 51 34	107.78
	11 39 43	114.03	11 54 53	106.96
	12 28 33	114.17	12 10 25	107.29
	12 32 51	113.38	12 14 51	107.49

Titan–Hyperion.

1896	East. Mean Time	p	East. Mean Time	s
Apr. 7	14 42 14	21.76	15 1 16	76.67
	14 48 54	22.10	15 4 19	76.97
	15 28 36	23.10	15 13 34	77.25
	15 35 2	23.81	15 16 14	76.84
15	13 18 18	102.51	13 48 8	71.66
	13 25 31	102.90	13 50 38	71.74
	14 16 47	102.59	13 53 15	71.16
	14 21 10	102.73	13 55 13	71.75

OBSERVATIONS OF ASTEROIDS,

MADE WITH THE 20-INCH EQUATORIAL OF THE CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, COLORADO.

By C. PERCY FONDA.

University Park M.T.		*	No. Comp.	Planet − * $\Delta\alpha$	Planet − * $\Delta\delta$	Planet's apparent α	Planet's apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
				(82) Alkmene.					
1898	h m s			m s	′ ″	h m s	° ′ ″		
Mar. 29	11 17 44	1	21	+1 13.77	. . .	13 41 13.16	. . . .	n9.336	. .
	11 20 16	1	9	. . .	− 5 59.8	. . . .	−10 6 45.5	. .	0.815
Apr. 14	11 17 54	2	6	. . .	− 3 57.5	. . . .	− 8 57 4.2	. .	0.817
	11 18 37	2	36	+0 40.32	. . .	13 27 14.36	. . . .	n8.842	. .
27	11 5 29	3	24, 9	+4 0.26	+ 0 35.1	13 16 27.25	− 8 11 19.8	8.444	0.813
	11 27 30	4	24, 9	−2 2.64	−12 10.6	13 16 26.99	− 8 11 31.4	8.842	0.812
				(176) Idunna.					
May 9	11 26 53	5	20	−0 26.33	. . .	15 21 38.17	. . . .	n8.925	. .
	11 27 8	5	6	. . .	+ 0 32.6	. . . .	− 2 40 31.4	. .	0.770
	11 53 33	6	12	+5 33.82	. . .	15 21 36.95	. . . .	n8.474	. .
	11 54 59	6	6	. . .	+ 2 26.8	. . . .	− 2 40 29.1	. .	0.770

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	13 39 56.47	+2.92	−10 0 27.0	−18.7	Munich I. 9482
2	13 26 30.93	+3.11	− 8 52 17.7	−19.0	Schjellerup 4834
3	13 12 23.87	+3.12	− 8 11 34.6	−20.3	Munich I. 9057
4	13 18 26.49	+3.14	− 7 58 30.6	−20.2	½(Munich I. 9140 + Schjellerup 4795)
5	15 22 1.15	+3.35	− 2 40 48.4	−15.6	Munich I 11371
6	15 15 59.78	+3.35	− 2 42 39.7	−16.2	½(Munich I. 11244 + Schjellerup 5446)

COMET *i* 1898.

[From Mr. Ritchie's Special Circular, No. 122.]

On the night of October 20 a telegram received from Dr. W. R. Brooks of Geneva, N.Y., announced the discovery of a comet earlier in the evening. The discovery-position and others received from Professor W. W. Payne of Northfield, Minn., and through Harvard College Observatory are here given. Professor Keeler of Lick Observatory communicates the elements and ephemeris computed by Hussey. The object as described by Brooks is large, round and brightish.

1898 Gr. M.T.	α	δ	Observer
	h m s	° ′ ″	
Oct. 20.5	14 32 10	+60 26 0	Brooks
21.6352	15 3 35.6	57 55 18	Hussey
22.6900	15 25 39.0	55 19 33	Wilson
23.6280	15 42 57.1	52 19 22	Hussey
24.6850	16 0 6.1	+49 50 19	Hussey

Elements and Ephemeris.

T = 1898 Nov. 23.14 Gr. M.T.

$$\left.\begin{aligned} \omega &= 123^\circ\ 22' \\ \Omega &= 96\ 10 \\ i &= 140\ 19 \end{aligned}\right\}\ 1898.0$$

q = 0.7564

1898 Gr. Midnight	α	δ	Brightness
	h m s	° ′	
Oct. 27	16 35 48	+41 31	1.08
31	17 9 8	30 11	
Nov. 4	17 30 28	20 30	
8	17 44 52	+12 41	1.91

Brightness October 20 = 1.

Computed from observations of October 21, 23 and 25.

Professor Keeler further telegraphs that Perrine notes a close resemblance between the elements of this comet and those of 1881 IV.

Mr. Ritchie also communicates the following orbit received by him from Carleton College Observatory, computed from observations of Oct. 21, 22 and 25, by Dr. H. C. Wilson.

T = 1898 Nov. 23.12 Gr. M.T.

$$\left.\begin{aligned} \omega &= 122^\circ\ 25' \\ \Omega &= 94\ 55 \\ i &= 140\ \ 4 \end{aligned}\right\}\ 1898.0$$

q = 0.7558

Gr. M.T.	α	δ	Br.
	h m s	° ′	
1898 Oct. 28.5	16 45 28	+38 34	1.12
Nov. 1.5	17 14 56	27 38	
5.5	17 33 56	18 29	
9.5	17 47 0	+11 9	0.73

A NEW VARIABLE OF THE *ALGOL*-TYPE.

[From Mr. Ritchie's Special Circular, No. 122.]

Mr. Edwin F. Sawyer communicates to the Boston Scientific Society the particulars of a new *Algol*-variable just discovered by him. It is DM. 12°3557, the position of which (1900) is R.A. $18^h\ 26^m\ 1^s$ +12° 32′ 36″. The epoch of minimum is 1898 October 3.54233. Gr. M.T., and the period is $21^h\ 21^m$. The range of variation is from 7.0 to 7.5 magnitude.

ELEMENTS OF THE MINOR PLANET *DQ*,

By WILLIAM J. HUSSEY.

From the mean of the two Kiel observations of August 15, and my observations of September 6 and 27, I have computed the following elements and constants for this planet. In obtaining the elements the observations have been fully corrected for parallax and aberration. The elements give a perihelion distance of 105,440,000 miles, or approximately 23,000,000 miles less than that of *Mars*, and only 14,100,000 miles greater than that of the *Earth*.

Constants for the Equator, 1898.0.

$$\begin{aligned} x &= r[9.994680]\ \sin(v+210^\circ\ 44'\ 5''.2) \\ y &= r[9.941724]\ \sin(v+115\ 43\ 8.4) \\ z &= r[9.707159]\ \sin(v+136\ 10\ 6.6) \end{aligned}$$

Elements.

Epoch 1898 August 31.5 Gr. M.T.

M = 222° 51′ 53″.3

$$\left.\begin{aligned} \omega &= 176\ 52\ 17.6 \\ \Omega &= 303\ 23\ 45.2 \\ i &= 10\ 44\ 44.3 \end{aligned}\right\}\ \text{Ecliptic and Mean Equinox of 1898.0}$$

$$\begin{aligned} \varphi &= 12\ 49\ 40.7 \\ \log a &= 0.164038 \\ \log \mu &= 3.303950 \\ \mu &= 2013''.491 \end{aligned}$$

Period = 643.66 days = 1.762 years

Mt. Hamilton Cal., 1898 *Oct.* 4.

CONTENTS.

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STANDARD STARS SOUTH OF DECLINATION $-20°$,

By LEWIS BOSS.

The subjoined catalogue of southern standard stars, together with tables of systematic corrections to be applied to various series of meridian determinations, while prepared primarily for the special use of the Dudley Observatory, may be found to have some general interest.

Essentially the present investigation constitutes an extension of the system of star-positions of the *American Ephemeris* from declination $-22°$ to the south pole. As to the right-ascensions, the system of the *American Ephemeris* (*A.E.*) to which reference is here made, is complete and definite only in the equatorial-zodiacal region. NEWCOMB's "Standard and Zodiacal Stars" and the "Declinations of Fixed Stars" by the present writer define this system. Twenty years ago, when the *A.E.* system was founded, the available interval embraced in the published meridian observations from the Southern hemisphere was, substantially, 1830 to 1870. Nearly all the observations of the Cape Observatory later than 1834 were at that time still unpublished; and the material was otherwise scanty. It was, therefore, practically impossible to establish a satisfactory system of star-positions for the far southern sky at that time. The *A.E.* system in right-ascension, as defined in the Standard and Zodiacal Stars, is, in fact, confined to the equatorial-zodiacal region, and is a system of "clock stars." The deficiencies of this system would not possess any special significance at the present time were it not that it is found to represent the whole course of observation during the nineteenth century so well that an investigation of some critical thoroughness will be needed to determine even the algebraic signs of the systematic corrections required. Therefore, it seems to be worth while to repair those deficiencies of the *A.E.* system, pending the time when by an extension of the interval of reliable fundamental determinations of star-position the opportunity for an effective revision of that system shall become evident.

The present work was begun, as part of a more comprehensive one, six years ago, but until last year was carried on in a desultory manner amid more pressing duties. Many years ago I selected about 750 stars with a view to their use as primary and secondary standards in the region $-22°$ to $-90°$. Of these about 500 were to be prepared for the use of the Dudley Observatory in carrying on meridian observations in the belt of sky, $-22°$ to $-37°$. The present publication contains the larger and better part of what I have termed the primary standards.

The practical end sought in the present work may be defined concretely thus: To construct a standard catalogue for the region south of $-20°$ such that the same results for star-position may be reached by means of strictly differential observations in any part of that region as would be reached through perfect instrumental and other observing conditions by the use of the equatorial stars of the *A.E.* system as standard. To construct such a normal system of southern standard stars requires a series of approximations by means of which the required systematic corrections of the separate star-catalogues and the resulting normal star-places are determined somewhat as if from virtually simultaneous equations.

It is assumed that the required systematic corrections for both right-ascensions and declinations can be expressed in terms of $\Delta\alpha_\alpha$ and $\Delta\delta_\delta$ for the former and $\Delta\delta_\alpha$ and $\Delta\delta_\delta$ for the latter. $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ are the customary corrections which vary with the declination either according to some simple law, or otherwise. I shall assume that $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ may usually be sufficiently well expressed under the form, $a \sin\alpha + b \cos\alpha$. The annual cycle of temperature suggests the possibility of errors having this form and may be the chief source of such terms; the variation of latitude originates a term of this form in $\Delta\delta_\alpha$; many small errors in the older catalogues due to defective constants of reduction are of this form; other sources of error may be approximately of this form. I have usually found in practice that, after the application of corrections $\Delta\alpha_\alpha$ or $\Delta\delta_\alpha$ of this form, the outstanding residual errors are relatively small in amount and irregular as to distribution.

It is obvious that, under the plan here adopted, corrections of the form $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ can be at once determined for all those southern star-catalogues which have a sufficient number of observations within the equatorial regions, $-20°$ to $+30°$. This course proves to be feasible in practice except for a limited number of star-catalogues like those of the Cape Observatory for 1830 and 1850. There practically remains, then, only the problem of finding $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ within the declination limits $-20°$ to $-90°$.

Right-Ascension. So far as the transit element is concerned, when the right-ascensions of clock stars ($+30°$ to $-20°$) are assumed to be known, each instrument is simply required to define a meridian in the sky. If the rotation of the line of collimation in a true plane be sufficiently insured through known excellence of pivots and rigidity of construction; and if the polar deviation of the transit has been determined by independent observation of the right-ascensions of polar stars; the observed right-ascensions may be considered absolute for the purposes here required. In the present work I have assumed that the required conditions are sufficiently fulfilled to permit the use of the following catalogues, with approximate relative weights, in constructing a normal system of right-ascensions for southern stars in the manner described: Cape Catalogues for 1830, 1833, 1840, 1860, 1880, 1885 and 1886 to 1891; Saint Helena 1830, Santiago 1850, Melbourne 1860, 1870 and 1880, and Cordoba 1875, — thirteen series in all. With two exceptions to be noted, the practice adopted in this preliminary stage of the computation is to consider $\Delta\alpha_\delta$ constant (correction of the adopted equinox) and to combine this with $\Delta\alpha_\alpha$ determined from equatorial ($-20°$ to $+30°$) stars.

Declinations. In the preliminary stage of the work $\Delta\delta_\alpha$ is determined in the same way as $\Delta\alpha_\alpha$ was determined. But even in the first approximation it was not desirable that $\Delta\delta_\delta$ should be regarded as constant. This part of the error may be assumed to be due to error in the adopted constant of refraction, to uncorrected flexure, or to some other source of error. While the form of correction due to assumed errors of flexure, or of refraction tables, is known, we must make some arbitrary assumption when the source of the error is not clearly indicated. Wherever the latitude has been adjusted in such a manner that the zenith-distances of close circumpolar stars give sensibly the same declinations at upper and lower culmination, we may assume that $\Delta\delta_\delta$ for the pole is zero. Through comparison with the *A.E.* system we are enabled to determine $\Delta\delta_\delta$ for the equator. In the absence of other expedients ve may then assume that $\Delta\delta_\delta$ varies uniformly from the equator to the pole. In effect, however, this is not very different from assuming that the correction is proportional to $\sin z$ for the declination limits under consideration.

Thus we have a first approximation to the required systematic corrections; and through the use of these with suitable weights the basis of the normal system was derived by combination of the thirteen catalogues enumerated to give the places of 114 stars. Then came a second approximation to the values of $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ obtained through comparison of the catalogues with the new standard catalogue. At this stage of the work the star-positions of Bradley 1755, Piazzi 1800, Brisbane 1825 (in declination only), Taylor's Madras 1835, and Cape 1850 were introduced and corrected for preliminary values of $\Delta\alpha_\delta$ and $\Delta\delta_\delta$, as well as for values of $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ ascertained by a combination of the equatorial with the new standard stars as a basis of comparison. Then the southern standard catalogue was expanded to 297 stars, 39 of the 114 preliminary star-places having been revised. This last catalogue, from which a selection of 179 stars has been made for publication in this article, became the basis for a final revision of the systematic corrections, as published in Table IV.

Basis in Right-Ascension.

In right-ascension, the foundation of the present investigation rests essentially on Professor Newcomb's "Right-Ascensions of the Equatorial Fundamental Stars." Professor Newcomb there investigated in an exhaustive way two important points, — the position of the equinox and periodic errors in observed right-ascensions of the form $a\cos\alpha + b\cos\alpha$. Subsequent investigation indicates that his success on both these points was good. The best modern observations indicate but a slight correction to his position and motion of the equinox. In his recent work upon the Fundamental Constants of Astronomy (pp. 88 and 96) Professor Newcomb states that from a treatment of all the most available observations of the sun made during the modern period of astronomical history he finds as the most probable correction of the equinox here in question, $-0^s.023\left(\frac{T-1852}{100}\right)$. In *A.J.* 430 (p. 172) the present writer deduces a similar correction of $-0^s.04\left(\frac{T-1854}{100}\right)$. From the Fundamental Constants (pp. 88 and 96) it is learned that, when he combines with the results of sun-observations those from *Mercury* and *Venus*, Professor Newcomb obtained for the correction of the Equinox of the *American Ephemeris*, $+0^s.020\left(\frac{T-1866}{100}\right)$, and this he appears to regard as the most probable correction. I doubt whether the results from *Venus* and *Mercury* ought to have any appreciable weight, not only because of certain difficulties connected with the theories of those planets, but also because of the very great uncertainties in the systematic sense which attach to observed right-ascensions of those planets. Whatever we decide, it seems

that the correction of the equinox *A.E.* (or N_1) must be quite small. Of course, the final correction for the motion of the equinox is one which may easily be left open for the last, since it is the easiest of all corrections to apply.

But it is extremely desirable that a standard system of clock-stars should be as free as possible from errors of the form $a \sin\alpha + b\cos\alpha$. Excellence in this respect appears to be the distinguishing feature of Professor Newcomb's work. He paid only incidental attention to systematic errors of the form $\Delta\alpha_\delta$. As to the error $\Delta\alpha_\alpha$, the most available and weighty of recent testimony on that point is contained in the two Greenwich Catalogues for 1880 and 1890 respectively. Each of them is wholly subsequent to and independent of Professor Newcomb's work. At Greenwich, with suitable methods and appliances, the most careful attention has been given to the elimination from observed right-ascensions of terms in $\Delta\alpha_\alpha$. Among the published papers on this point we may select that by Professor Newcomb (*M.N.*, June, 1890) which contains the detailed results of a comparison of the Greenwich Ten-Year Catalogue for 1880 with the *A.E.* standard in right-ascension; also a recent paper by the Astronomer Royal (*M.N.* for April, 1898) embodying the results of a similar comparison with the Ten-Year Catalogue for 1890. From a summary discussion of these two I find the following corrections of the *A.E.* system:

From Grw. 1880	$+0^s.001 \sin\alpha$	$-0^s.005 \cos\alpha$
From Grw. 1890	$+0.001 \sin\alpha$	$+0.003 \cos\alpha$
Mean epoch 1887	$+0.001 \sin\alpha$	$-0.001 \cos\alpha$

The agreement could not be more satisfactory. In fact the coefficients of correction are much smaller than their probable error of determination.

I have considered the *A.E.* system in R.A. to be best defined by the places of the principal stars given for five-year intervals on pp. 301 to 314 of Professor Newcomb's Standard Clock and Zodiacal Stars. The right-ascensions of other stars given in that work are liable to large errors in individual instances.

Basis in Declination.

I have tested the *A.E.* system of declinations in a similar manner. This system may be said to give a seemingly good representation of the combined testimony of observation as to declinations of stars as that testimony existed in published form twenty-two years ago. Many new contributions have appeared since that time, although these are less in number and, except a few, less valuable than one might fairly have expected. For the present purpose it is only necessary to consider the new material of very early or very recent date. Obviously the new material will have no value as a test of the standard declinations unless it shall be constituted of independent determinations.

Strictly speaking, no determination of the declinations of stars can be considered as independent when the constant of refraction is not independently determined but is assumed to be known. No matter how perfectly the physical constants of refraction may have been determined in previous researches, there will always be great difficulty in obtaining the true temperature of the air, or the temperature corresponding with that which ought to be used in connection with the adopted tables, which themselves may be founded on thermometer-readings that did not give the true temperature of the air. The delicacy of this point is such that a systematic error of 1° *C* in the reading of the thermometer produces a systematic error in the zenith-distances of about $0.0035\,\rho$, where ρ denotes the refraction in seconds. It can scarcely be asserted that in the various methods of exposure of the thermometer we can be insured against a systematic uncertainty of this amount, though it may well chance to be less. But, if we have two contemporaneous series of observed declinations of stars determined in opposite hemispheres, though each, standing alone, may not be strictly independent as to determination of refraction, comparison of the two series offers an excellent means for the systematic correction of the refraction at each observatory. The value of this means depends upon the freedom from instrumental error of the zenith-distance measures. An example of this kind of comparison may be found at pages 66–68 of my work on Declinations of Fixed Stars, where my compilation of Washington declinations (1866–69) is compared with the Melbourne Catalogue for 1870. Another example is found in the introduction of the Cape Catalogue for 1885. Dr. Gill has there presented evidence to show that the Cape Circle is probably not affected with appreciable errors of flexure of the form $b\cos z$ (pp. xxv–xxix). The errors of graduation both for the Greenwich and Cape Circles seem to have been determined with great care, and much evidence might be adduced to prove that the casual errors of graduation are small. I think that this combination of the work of the two observatories furnishes evidence of independent value as to the declinations of the principal stars, not equal, perhaps, to that which might have been derived from two reversible instruments in like relations, but certainly worthy of much confidence. In much the same way I have utilized the recent annual catalogues of the Cape Observatory, 1886–1891, in combination with the unpublished Greenwich Catalogue for 1890. Dr. Gill finds the latitude of the Cape Transit Circle to be $-33° 56' 3''.54$. This is strikingly confirmed by observations made with the zenith-telescope upon stars at upper and lower culmination at the Cape combined with stars at equal zenith-distances north, the declinations of which were determined at

Pulkowa. Neglecting possible secular variation of latitude we are thus in possession of what might be termed the absolute latitude of the Cape Circle as determined with the supplementary aid of the observatory at Pulkowa. Assuming that the correction for flexure of the Cape Circle is $-0''.30 \sin z$, we have as the correction of the declinations, 1886–1891, as printed, $-0''.34 - 0''.30 \sin z$. The declinations thus corrected I have compared with my standard catalogue, *A.E.* For the two zones south of $-20°$ I show the results as they would appear, using the standard declinations of the present paper. In a second column I add the results of a like comparison of the unpublished results of the Greenwich Ten-Year Catalogue for 1890 with *A.E.*, as made by the Astronomer Royal and published in the *Monthly Notices* for April, 1898.

A.E. — Cape 89 and *A.E.* — Greenwich 90. Declination.

Decl.	*A.E.*-Cp.	*A.E.*-Gr.	Decl.	*A.E.*-Cp.	*A.E.*-Gr.
° °	″	″	° °	″	″
−30 to −25	+0.11	+0.13	+20 to +30	−0.11	−0.10
−25 to −20	−0.02	+0.43	+30 to +40	−0.14	−0.09
−20 to −10	−0.05	+0.10	+40 to +45	−0.57	−0.22
−10 to 0	+0.02	+0.07	+45 to +48	−1.21	
0 to +10	+0.01	+0.09	+48 to +50	−1.23	
+10 to +20	+0.09	+0.18			

From the foregoing is easily derived a comparison of the two catalogues which is exhibited in the next table. The second column, "obs.," contains the numbers resulting directly from the comparison; the last column exhibits these numbers corrected for the effects of systematic correction of the refraction.

Greenwich 90 — Cape 89.

δ	G.—C. Obs.	Corr.	δ	G.—C. Obs.	Corr.
°	″	″	°	″	″
−27	−0.32	−0.12	+25	−0.01	+0.14
−23	−0.45	−0.30	+35	−0.07	+0.13
−15	−0.15	−0.02	+42	−0.35	−0.06
− 5	−0.05	+0.06	+46	−0.99	−0.61
+ 5	−0.08	+0.04	+48	−1.01	−0.54
+15	−0.09	+0.04			

Bessel's refractions were employed in deducing the declinations at each observatory. If the mean refractions at the Cape had been multiplied by $(1-0.0011)$ and at Greenwich by $(1-0.0006)$ with the corresponding change of latitude $(0''.03)$ for Greenwich, and if the catalogue-declinations had been corrected accordingly, the comparison would have resulted as in the last column above. The corrections are in this instance very slight, though there are indications that they are not wholly satisfactory at large zenith-distances. For zenith-distances much less than 80° it is apparent that the declinations of the two observatories are in this way substantially harmonized.

We have now available for testing the *A.E.* system, the declinations of the Pulkowa Catalogue for 1885, and the corrected declinations of the two latest Greenwich and the two latest Cape Catalogues. I have arranged the result in condensed tabular form, thus:

Observed Corrections of *A.E.* in Declination.

	+35°	+25°	+15°	+5°	−5°	−15°
	″	″	″	″	″	″
Gch. 82	+0.16	+0.07	−0.20	+0.03	+0.11	+0.17
Cape 84	+0.05	−0.01	−0.20	+0.02	−0.04	+0.10
Pulk. 85	−0.14	−0.17	−0.32	−0.20	−0.26	+0.14
Cape 89	−0.02	+0.05	−0.16	−0.07	−0.06	+0.08
Gch. 92	+0.11	+0.18	−0.09	−0.04	+0.02	+0.01
Mean(86)	0.00	−0.01	−0.22	−0.08	−0.08	+0.11

The means are formed by assigning to Pulkowa twice the weight assigned to each of the other series. Except in the zone $+20°$ to $+10°$, the evidence of systematic difference is seen to be wholly insignificant. But it appears that the standard declinations in the vicinity of $+15°$ require a small negative correction at the epoch 1886. It may also be remarked that the result would have been practically the same, even if the Greenwich and Cape declinations had received no correction for refraction. As to the correction of the form $\Delta\delta_\alpha$ we have the following:

From Gch. 82	$-0''.06 \sin\alpha$	$-0''.04 \cos\alpha$
Cape 84	$0.00 \sin\alpha$	$-0.08 \cos\alpha$
Pulk. 85	$+0.03 \sin\alpha$	$-0.01 \cos\alpha$
Cape 89	$+0.04 \sin\alpha$	$0.00 \cos\alpha$
Gch. 92	$+0.02 \sin\alpha$	$-0.02 \cos\alpha$

Except at Pulkowa, where an attempt has been made to eliminate the effect of variable latitude, these corrections in $\Delta\delta_\alpha$ are not entitled to much weight; but they do indicate that the correction, $\Delta\delta_\alpha$, required by the *A.E.* system in 1886 must be very small. In this connection, the inactivity in meridian observation of independent value at observatories in the Southern hemisphere differing widely in longitude from those in Europe is very greatly to be regretted; because the combination of observations in opposite longitudes tends to eliminate terms in $\Delta\delta_\alpha$ which arise from variation of latitude.

In *A.J.* 364 (p. 28) Dr. Chandler has compared with the declinations of the *A.E.* system his new deduction of declinations from double zenith-distances measured with the Greenwich Mural Circles in the period, 1825–1848, mean epoch 1832.5. Part of these observations entered into the construction of the *A.E.* system; but Pond's observations subsequent to 1825 had no part in founding that system. The series is reduced with Bessel's refraction, and lacks independence in that respect. The positions are all of stars north of the equator. Yet, I think the comparison has some interest for the present purpose. Collecting the observed values, Gch. 32 — *A.E.*, in zones of 10° in width, we have the following corrections of the *A.E.* declinations in the equatorial regions:

GREENWICH 1832 — *A.E.* IN DECLINATION.

δ	$\Delta\delta_\delta$	$\Delta\delta_\alpha$
$+8^\circ$	$+0''.01$	
$+14$	$+0.01$	$-0''.04 \sin\alpha \quad +0''.10 \cos\alpha$
$+26$	-0.02	

Dr. CHANDLER finds confirmation of the periodic part of this correction through theoretical considerations. He says: "But, of the catalogues before 1850 on which BOSS's normal system rests, thirteen (wt. 25) were reduced by the use of nadir or horizontal points, and five (wt. 18) by polar points. The former are affected by latitude-variation, the latter not. Hence we reduce the above coefficient and take $+0''.11 \sin(\alpha + 113^\circ)$ as the correction to BOSS's declinations for the epoch in question." It seems to me that Dr. CHANDLER neglects the compensating effect of morning observations with the meridian instruments of the principal observatories. These to the extent in which they are actually made, tend still further to eliminate the annual term of latitude-variation for those bright stars under consideration in Dr. CHANDLER's comparison. This hypothesis seems to derive support from that part of the preceding comparisons of *A.E.* with late Greenwich Catalogues which relates to $\Delta\delta_\alpha$. I should, therefore, be inclined to think that the *A.E.* system for 1832 requires a correction of the form $\Delta\delta_\alpha$ smaller than that which is indicated by Dr. CHANDLER's treatment of POND's double altitudes.

In his discussion of the orbits of the principal planets Professor NEWCOMB has derived terms representing the absolute correction of the *A.E.* system of declinations. From the discussion of five planets, *Mercury* to *Saturn*, he indicates at p. 89 of his Fundamental Constants of Astronomy that the *A.E.* system of declinations may require, in the equatorial region, a correction of

$$+0''.09 \quad +0''.42\,T$$

in which T is the fraction of a century elapsed since 1850. In *A.J.* 365 he repeats this statement and remarks: "The correction for the epoch 1850 I regard as quite reliable, and probably correct within $\pm 0''.07$. The secular term, however, is less reliable, owing to the difficulty of reducing the older observations to any one standard with entire certainty."

I should feel some distrust of both terms, principally for two reasons. *First*, nearly all the observations which are effective for correcting the planetary tables have been made at observatories which have a comparatively high northern latitude; so that fully one-fourth, or one-third, of the planetary zenith-distances, must be measured under circumstances unfavorable for computing the true amount of refraction in comparison with those observations which have been made at small zenith-distances. The true equator will not therefore be at the theoretical mean indicated by the observations treated in this manner; and in order for this method to be effective the observatories should have very small latitudes. *Secondly*, there is a well known uncertainty in the pointing in zenith-distance upon planetary images; there is every probability that small but tenacious systematic errors would originate in this source, — errors which have already been indicated in corresponding meridian observations of *Mars*; and such errors would almost certainly operate more sensibly at the greater zenith-distances. But if we suppose the correction derived from the planets to have some weight, we may arrange the new observed corrections of the *A.E.* system of declinations near the equator as follows:

Date	Obsd. Corr. of *A.E.*	Source
1832	$0''.00$	Greenwich Mural Circles, 1825–1848.
1850	$+0.09$	Planetary researches.
1886	-0.07	Recent Greenwich and Pulkowa obsns.

Furthermore, the *A.E.* system of declinations should be most free from systematic error in 1847, which is the mean epoch of the fundamental declinations employed in its foundation. Therefore we may insert the value zero, at the date 1847, in the above list. Then it becomes clear that the latest Greenwich, Cape, and Pulkowa observations indicate a negative progressive alteration in the correction for the *A.E.* system. This, however, is directly opposed to that which Professor NEWCOMB finds through his planetary researches; and also it is directly opposed to that which would result from the comparison of the new reduction of BRADLEY's observations by Dr. AUWERS with modern observations.

In the following statement of the results of comparison between the *A.E.* standard declinations and those of BRADLEY between $+50^\circ$ and -20° of declination only the principal standard stars are employed. South of -20°, results derived by the use of the catalogue at the end of this paper are appended.

AUWERS–BRADLEY — *A.E.* DECLINATION.

δ	No. Stars	Wt.	$\Delta\delta_\delta$	R.A.	No. Stars	$\Delta\delta_\alpha$
$+47^\circ$	9	2.9	$-0''.92$	1^h	11	$-0''.04$
$+36$	13	2.6	-2.29	3	12	$+0.34$
$+25$	21	1.4	-1.39	5	13	$+0.24$
$+15$	24	5.5	-1.60	7	6	0.00
$+5$	27	5.8	-1.55	9	8	-0.22
-6	21	1.8	-1.32	11	10	-0.39
-15	13	2.7	-1.52	13	8	$+0.11$
				15	12	$+0.31$
-23	19	2.7	-1.53	17	10	$+0.10$
-27	20	1.4	-1.02	19	12	-0.71
-32	19	0.4	-1.14	21	15	-0.34
-34	3	. .	$+5.1$	23	11	$+0.64$

The weights are intended to be upon a scale of which the probable error of the unit is $\pm 0''.3$.

For the equatorial region I deduce as correction of the *A.E.* system in declination at the epoch of BRADLEY's observations:

$$-1''.50 \quad +0''.02 \sin\alpha \quad +0''.15 \cos\alpha$$

The probable error of the coefficients of the periodic term is $\pm 0''.11$ and, consequently, they have not much significance. The question whether BRADLEY's declinations ought to have any appreciable weight in the foundation of a normal system is one which I shall not now discuss further than to remark that this weight should certainly not be large enough to produce in the adopted relations of the modern catalogues any marked distortion.

I, therefore, conclude that the *A.E.* system in declination is a fair approximation to the truth. I do not, indeed, feel justified at present in indicating an opinion whether the progressive error of the system at the equator is in the positive or negative direction. I prefer to await further observations of independent value before entering upon the final stages of the revision which I have in hand. It is assumed, therefore, that the *A.E.* system, in both coordinates, offers a suitable basis for the construction of a normal system of Southern Standard Stars.

But many of the individual declinations of the standard catalogue are easily susceptible of material improvement. I have adopted the following corrections in the course of the present work; the constant term is the correction for 1875.

	$\Delta\delta$ 1875	$\Delta\mu'$	
	$''$	$''$	
ζ *Andromedae*	−0.38	−0.0110	$(T-1875)$
μ *Andromedae*	+0.29	+0.0132	$(T-1875)$
51 *Cephei*	+0.17	+0.0081	$(T-1875)$

ϵ *Hydrae* (No. 138) for $34''.59$ read $33''.59$; corr. in Newc. Standard and Zodiacal Stars, and in the *Amer. Ephem.*

β *Urs. Maj.*	+0.38	+0.0153	$(T-1875)$
δ *Crateris*	+0.30	+0.0113	$(T-1875)$
γ *Cor. Bor.*	+0.64	+0.0175	$(T-1875)$
ϵ *Serpentis*	−0.18	−0.0066	$(T-1875)$
γ *Herculis*	−0.36	−0.0100	$(T-1875)$
λ *Ophiuchi*	+0.38	+0.0131	$(T-1875)$
κ *Ophiuchi*	−0.10	−0.0042	$(T-1875)$
η *Serpentis*	−0.72	−0.0290	$(T-1875)$
ϵ *Delphini*	−0.22	−0.0046	$(T-1875)$
o *Andromedae*	+0.39	+0.0124	$(T-1875)$

There is also a decided number of misprints in the Catalogue of the Declinations of Fixed Stars which, in part, owe their explanation to the fact that, through an annoying blunder, none of the proof-sheets after page 578 (or [172]) were submitted to me. During this time one section of the work was wholly omitted in printing. The omission to send me these proof-sheets was the more to be regretted because the manuscript for the printer had to be prepared in haste to meet an unavoidable official requirement.

PRELIMINARY SYSTEMATIC CORRECTIONS.

Following is a list of preliminary systematic corrections by the employment of which the places of 114 stars south of declination −20° were computed to serve as the essential basis of the southern system.

PRELIMINARY CORRECTIONS IN R.A.

Cape 30	$+0^s.023$	$+0^s.025 \sin\alpha$	$+0^s.019 \cos\alpha$	$+0^s.065\, tg\,\delta$
S.H. 32	−0.016	$-0.011 \sin\alpha$	$-0.015 \cos\alpha$	$-0.065\, tg\,\delta$
Cape 33	+0.010	$-0.012 \sin\alpha$	$-0.009 \cos\alpha$	
Cape 37	0.000	$-0.012 \sin\alpha$	$-0.003 \cos\alpha$	
So. 51	−0.012	$-0.015 \sin\alpha$	$+0.019 \cos\alpha$	
Cape 59	+0.023	$-0.006 \sin\alpha$	$+0.010 \cos\alpha$	
Melb. 62	+0.045	$-0.033 \sin\alpha$	$+0.007 \cos\alpha$	
Melb. 68	+0.022	$-0.032 \sin\alpha$	$+0.011 \cos\alpha$	
Cord. 76	+0.005	$-0.023 \sin\alpha$	$+0.019 \cos\alpha$	
Melb. 76	+0.036	$-0.004 \sin\alpha$	$+0.026 \cos\alpha$	
Cape 76	+0.010	$-0.010 \sin\alpha$	$+0.005 \cos\alpha$	
Cape 84	+0.019	$-0.010 \sin\alpha$	$0.000 \cos\alpha$	
Cape 89	+0.024	$-0.006 \sin\alpha$	$+0.004 \cos\alpha$	

PRELIMINARY CORRECTIONS IN DECLINATION.

Cape 31	$+0''.0050$	$(90°+\delta)$	$+0''.22 \sin\alpha$	$+0''.08 \cos\alpha$
S.H. 31	0.5	$(B-Y)$	$+0.27 \sin\alpha$	$+0.47 \cos\alpha$
Cape 33	$(\rho+86'')$	(-0.0013)		
	$+1''.25$	$(\cos z-0.56)$	$-0.01 \sin\alpha$	$-0.07 \cos\alpha$
Cape 37	$(\rho+86'')$	(-0.0013)	$+1.25 (\cos z$	$-0.56)$
So. 51	$+0''.0150$	$(90°+\delta)$	$+0.24 \sin\alpha$	$-0.18 \cos\alpha$
Cape 59	$(\rho+86'')$	(-0.0015)	$+0.06 \sin\alpha$	$+0.01 \cos\alpha$
Melb. 62	$+0''.0100$	$(90°+\delta)$	$-0.06 \sin\alpha$	$-0.28 \cos\alpha$
Melb. 68	$-0''.27$	$-0.0018\,\rho$	for stars north of zenith	
	$(\rho+72'')$	(-0.0037)	for stars south of zenith	
Cord. 76	$(\rho+94'')$	(-0.0038)	$-0.18 \sin\alpha$	$+0.05 \cos\alpha$
Melb. 76	correction for Melb. 68		$-0''.0020$	$(90°-\delta)$
Cape 76	$(\rho+86'')$	(-0.0011)		
Cape 84	$(\rho+86'')$	(-0.0022)	$+0.00 \sin\alpha$	$+0.08 \cos\alpha$
Cape 89	$-0''.34$	$-0.0011\,\rho$	$-0.30 \sin(326°\ 4'-\delta)$	

ρ is the mean refraction, considered positive north of the zenith. "$B-Y$," in the expression for the correction of S.H. 31 in declination, signifies the difference between BESSEL's and YOUNG's refractions as exhibited in the table which JOHNSON gives at p. 22 of the introduction of the Saint Helena Catalogue.

As to the choice of catalogues enumerated in the foregoing list little need be said in addition to the statements in a previous paragraph. It seemed better not to include any of the observations made at northern observatories in this first stage of the investigation, because, for observations near and beyond 70° of zenith-distance, anomalous variations in the required systematic corrections are to be expected. Catalogues in which the number of observations of the principal stars is scanty, or badly distributed over the sky, are not here included. From the sketch of the process of computation already given it may be seen that it is not necessary that the catalogues selected should be of undoubted value as absolute determinations of star-positions in the most complete sense. It was only necessary that they should sufficiently fulfil the conditions required in determining a true meridian in right-ascension with a fair degree of probability, with a like probability in favor of the expectation of the value zero for $\Delta\delta_\delta$ at, or near, the southern pole.

There might be felt some doubt whether FALLOWS's Cape and JOHNSON's Saint Helena Catalogues sufficiently corre-

spond to these requirements, — especially as to right-ascension. Owing to the lack of equatorial stars, $I\alpha_a$ and $I\delta_\delta$ for Cape 30 had to be determined in part differentially from other catalogues. At both observatories adjustment was depended upon for reducing the errors of the transit-plane to zero. The evidence necessary for testing the polar deviations of the transit is very scanty, though better in the observations of FALLOWS than in those of JOHNSON. If, however, we take the evidence of JOHNSON's right-ascensions north of the zenith of Saint Helena, his transit must have described very nearly a true meridian plane. With the aid of POND's, STRUVE's and ARGELANDER's Catalogues for 1830 as an intermediary term of comparison for stars north of $+45°$ of declination I obtain the corrections for JOHNSON's Catalogue here given in summary form.

δ	No. Stars.	*A.E.* − *S.H.*
°		s
+56	13	−0.040
+18	24	−0.040
−11	69	−0.010

This gives some ground for confidence in the right-ascensions south of the zenith. But when comparison is made with the right-ascensions of FALLOWS south of $-20°$ I find:

$$S.H. - \text{Cape} = +0^s.039 \ +0^s.130 \ tg\,\delta.$$

Means for ascertaining the polar deviation of the transit of FALLOWS is afforded by a large number of successive transits of *β Hydri* at upper and lower culmination. The instrument was probably quite accurately made and appears to have been rigid in all essential points. In view of all the circumstances it seemed to me that these two series of right-ascensions are entitled to about equal weight for the purpose here in view.

The plan of selection of the 114 stars serving as the foundation of the system both in α and δ is that each star shall be contained in the Catalogues of *S.H.* 1830, Cape 1833, Cape 1840, and Cape 1860; though the rule was slightly relaxed here and there as to the latter two Catalogues. In order, then, to bring in the right-ascensions of FALLOWS to the best advantage, the term in $tg\,\delta$ from *S.H.* — Cape was divided equally between the two catalogues as a preliminary correction; so that for the many stars which FALLOWS did not observe the systematic influence of his observations is still felt through the modified right-ascensions of *S.H.* 32.

WEIGHTS AND PROBABLE SYSTEMATIC ERROR.

A system of weights was next devised through the comparisons of each catalogue with the *A.E.* standard. In deciding upon the weights importance was attached to the probable value of the catalogue in a systematic sense. This was not always assumed to be proportional to the value in a differential sense. The practical effect of the decision in each instance is exhibited in the columns headed "Wt." in Table I. The number of observations for each star varies very decidedly in Cape 37, Cape 59 and other catalogues, so that the weights actually assigned to these authorities in the computation of place for a star may be decidedly greater or less than that given in the table which is a mean value for the 114 stars.

In both R.A. and decl. it is assumed that the positions have the greatest weight, in the systematic sense, in 1867.5. The mean weight of centennial motion in R.A. is 3.1 and in declination it is 3.5. We have thus the means for computing the mean weight of a star-position for any date, which may be regarded as the relative weight of the system for that date. For instance, opposite Cape 37 (1840), to which was assigned the relative weight of 7 in founding this southern system, we find in the columns headed "Comp. Wt." as the weight of the computed star-position of that date, 25 in R.A. and 27 in declination, of which 7 units were contributed by Cape 37 itself. Thus the systematic uncertainty of the Standard Catalogue is nearly twice as great in 1837 and 1897 as it is in 1867. It is not easy to express this uncertainty in numbers to the satisfaction of critical objection. However, I have computed the probable error of the system as it would result from the numbers in Table II. Thus I find the probable errors of the units of weight in Table I to be $\pm 0^s.028 \sec\delta$ and $\pm 0''.43$, respectively in R.A. and decl. It results that the systematic probable errors in 1867.5 are $\pm 0^s.003 \sec\delta$ and $\pm 0''.04$; while for the centennial motions the probable errors are $\pm 0^s.016 \sec\delta$ and $\pm 0''.24$. For 1900 the probable errors of the system become $\pm 0^s.006 \sec\delta$ and $\pm 0''.09$; and in 1910, $\pm 0^s.007 \sec\delta$ and $\pm 0''.11$. Considering any given restricted area in the southern sky separately, we may say that there is not quite an even chance that the catalogue at the end of this paper is systematically in error by $0''.1$ in either coordinate at the present time; while the chance is only one in forty that the systematic error now exceeds $0''.3$ for that area.

TABLE I. FUNDAMENTAL WEIGHTS.

	R.A.		Declination	
	Wt.	Comp. Wt.	Wt.	Comp. Wt.
Cape 30	2	18	1	21
S.H. 30	2	19	3	21
Cape 33	6	21	8	23
Cape 37	7	25	7	27
So. 51	2	53	3	56
Cape 59	9	81	9	83
Melb. 62	6	94	3	91
Melb. 68	10	100	9	100
Cord. 76	15	81	15	83
Melb. 76	10	81	7	83
Cape 76	8	81	9	83
Cape 84	11	53	12	56
Cape 89	12	40	14	43

The Argentine General Catalogue.

A difficulty has arisen in the use of the Cordoba declinations. The instrument was usually reversed at the beginning of each year and, from time to time, the zero of circle-graduation was brought into a new relation with reference to the line of collimation of the telescope. These practices have given rise to small systematic differences between the declinations of different years — differences which I have carefully investigated. Some little doubt might arise as to what ought to be regarded as the true mean of reference for the catalogue as a whole. For the present purpose I have considered this to be the indiscriminate mean for the observations of Lacaille-stars, which is equivalent to giving a decidedly larger weight systematically to the declinations in the years from 1874.0 to 1877.0. In the preliminary work of the present investigation I have employed small systematic corrections especially ascertained for the purpose of bringing the declinations of different years into harmony with those of the adopted mean. In right-ascension, also, there is a decided systematic difference between the respective results for clamp east and west. From all the observed differences, W. — E., I deduce the following table to express the half difference.

Cordoba Right-Ascensions; $\frac{1}{2}$ (W. — E.).

δ	$\frac{1}{2}$(W.—E.)	δ	$\frac{1}{2}$(W.—E.)
°	s	°	s
0	—0.006	—30	+0.023
— 5	—0.001	—35	+0.027
—10	+0.004	—40	+0.028
—15	+0.009	—45	+0.029
—20	+0.014	—50	+0.030
—25	+0.018	—85	+0.030

If the above numbers be applied to the right-ascensions of the years when the instrument was in the position, clamp east, and with reversed sign to the other years, clamp west, the systematic differences between the two sets of results will be practically extinguished. The star-positions of the Argentine General Catalogue which are of an epoch subsequent to the year 1880 seem to be of inferior accuracy, and I have employed them with diminished weights.

Determination of the Final Systematic Corrections.

By means of the preliminary systematic corrections and weights described, the positions of 114 principal southern stars, nearly all well observed by Henderson, were computed. With the aid of this new standard catalogue the preliminary systematic corrections were next revised; and at a later stage of the work all except Cape 33, Cape 84 and Cape 89 were revised again. In most instances, no important alteration in the systematic corrections resulted from the last revisions. In these revisions, with a standard catalogue as a basis, the variations of $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ could be studied; but, as a rule, $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ adopted in the preliminary operations were subsequently but little modified. Table II indicates what corrections were necessary to be applied to the preliminary corrections in order to represent the entire difference between each of the separate catalogues and the standard catalogues. When these observed corrections are added to the preliminary corrections, they exhibit the observed systematic correction from which the adopted corrections of Table IV were constructed. The values of $\Delta\alpha_\delta$ in Table II are multiplied by $\cos\delta$ in order to reduce all the numbers in a column to the same unit. These numbers in Table II show the amounts by which the discrepancies between the catalogues failed to be accounted for by the preliminary systematic corrections. This exhibit seems to me quite satisfactory, especially in right-ascension. It will be noticed that there is great uniformity in the values of $\Delta\alpha_\delta \cos\delta$ for Cape 37; and this would have been still very satisfactory, even if Cape 37 had been discarded in forming the normal system.

For the purpose of computing further positions of stars, which, though well observed since 1855, are somewhat deficient in observations previous to that time, I have thought it advisable at this stage of the work to introduce the determinations contained in Auwers-Bradley, 1755; Piazzi, 1800; Brisbane, 1825, in declination; Madras, 1835; and Cape, 1850; and with the help of the normal catalogue of 114 stars, which I have already described, I computed systematic corrections for these catalogues. Bradley's determinations cease to be numerous or appreciably serviceable south of —30°, and for all the stars of this paper Greenwich observations are at zenith-distances greater than 72°. Notwithstanding this, and the small weight of the other catalogue cited, they have doubtless added sufficiently to the weight of determination of proper motion to repay the labor spent upon that section of the work. The late Madras observations, Moesta's Santiago Catalogues, the Washington observations, and some others might also have been employed. I considered, however, that these would come in with greater economy of labor at a later stage of the operations, especially whenever the *A.E.* system shall be made to apply accurately to a larger number of stars in the equatorial region. It is from these stars that $\Delta\alpha_\alpha$ can best be determined; and they are of great importance in the determination of $\Delta\delta_\alpha$.

Owing to lack of well observed standard stars in the equatorial belt, special devices and much care were required in order to ascertain the systematic corrections needed for Cape 50. Nevertheless the first approximations to the systematic corrections derived partly by means of the 114 standard stars for this and others of the additional catalogues enumerated did not seriously differ from the final corrections as exhibited in Table IV.

TABLE II. OBSERVED CORRECTIONS OF PRELIMINARY SYSTEMATIC CORRECTIONS.

Cape 30.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	18	−0.013
30	12	−0.010
36	12	−0.011
42	12	−0.025
48	11	−0.018
55	17	+0.004
61	11	+0.011
67	11	−0.028
78	4	−0.020

S.H. 32.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	19	+0.006
28	23	−0.017
31	20	−0.020
34	18	−0.019
37	17	−0.023
41	17	−0.008
44	20	−0.007
49	19	−0.005
54	26	−0.015
60	27	−0.011
65	24	+0.008
70	18	−0.005
78	9	+0.002
85	7	+0.09

Cape 33.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	27	+0.005
30	17	+0.011
34	22	+0.031
42	24	+0.005
48	20	+0.009
55	21	+0.007
59	35	+0.002
67	21	+0.008
77	13	+0.001
85	16	−0.007

Cape 37.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	77	+0.007
30	63	+0.016
35	73	+0.004
42	42	+0.006
50	58	+0.019
58	54	+0.013
65	61	+0.019
77	39	+0.017
85	50	+0.004

So. 51.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	27	−0.016
31	21	−0.018
38	9	−0.016
57	42	−0.001
62	18	+0.004
69	12	−0.015
78	12	+0.014

Cape 59.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	66	0.000
30	67	+0.016
37	64	+0.026
45	66	+0.028
56	66	+0.033
65	60	+0.027
76	35	+0.004
82	24	+0.004
87	30	−0.010

Melb. 62.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	48	−0.012
30	39	−0.019
35	20	−0.002
43	26	−0.018
59	34	−0.030
68	40	−0.007
73	10	+0.007
79	22	+0.012
84	26	+0.011
88	4	−0.002

Melb. 68.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	63	−0.003
30	51	−0.010
36	35	+0.001
42	41	+0.002
48	50	−0.005
54	38	−0.002
59	51	−0.007
66	68	−0.017
76	55	−0.011
82	41	−0.003
85	37	−0.002

Cord. 76.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	100	−0.010
29	52	−0.014
34	32	−0.032
37	30	−0.036
42	52	−0.025
47	38	−0.024
55	56	−0.027
63	32	−0.028
68	46	−0.019
76	97	−0.004
82	70	+0.001
86	33	+0.005

Melb. 76.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	49	+0.016
29	24	+0.017
35	17	+0.015
53	20	+0.004
59	21	+0.007
67	17	−0.006
76	28	−0.013
81	14	−0.014
84	22	−0.006
88	12	−0.004

Cape 76.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	73	+0.018
30	56	−0.013
36	43	−0.008
42	38	+0.005
50	52	+0.019
60	64	−0.024
67	31	+0.003
76	32	+0.005
85	38	−0.007

Cape 84.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
24	119	−0.002
30	79	+0.010
36	34	−0.009
42	33	−0.009
50	65	−0.004
60	85	+0.010
68	16	+0.017
78	36	+0.003
85	82	+0.007

Cape 89.

δ (°)	Wt.	$\Delta\alpha\cos\delta$ (s)
23	95	−0.007
30	86	−0.005
36	62	+0.015
42	55	+0.007
51	85	+0.004
59	106	+0.011
68	27	+0.027
77	33	+0.010
84	41	−0.002

Cape 30.

δ (°)	Wt.	$\Delta\delta$ (″)
33	1	−0.21
45	1	+0.37
57	3	−0.03
66	1	−0.31
78	1	+1.0

S.H. 31.

δ (°)	Wt.	$\Delta\delta$ (″)
24	8	−0.84
28	8	−0.23
31	8	−0.75
34	7	−0.06
37	8	+0.21
41	7	+0.75
44	8	+0.42
49	7	+0.50
54	8	+0.25
60	8	+0.38
65	7	+0.34
70	5	+0.83
78	3	+0.69
85	3	−0.01

Cape 33.

δ (°)	Wt.	$\Delta\delta$ (″)
24	20	+0.56
30	14	+0.38
35	13	+0.42
39	19	+0.34
43	13	+0.02
48	19	−0.13
54	19	−0.04
60	33	−0.07
67	16	−0.07
77	11	−0.17
85	20	+0.02

Cape 37.

δ (°)	Wt.	$\Delta\delta$ (″)
24	31	−0.07
30	33	−0.11
36	35	−0.29
42	32	−0.32
47	21	−0.44
55	23	−0.44
61	30	−0.57
68	14	−0.40
77	12	−0.28
85	19	−0.10

So. 51.

δ (°)	Wt.	$\Delta\delta$ (″)
26	15	+0.03
36	5	−0.79
46	9	+0.05
57	15	+0.32
65	13	+0.15
77	5	+0.16

Cape 59.

δ (°)	Wt.	$\Delta\delta$ (″)
24	41	+0.26
30	48	+0.25
37	47	+0.13
45	46	+0.29
55	52	+0.31
63	26	+0.23
68	29	+0.40
78	21	+0.07
85	29	+0.05

Melb. 62.

δ (°)	Wt.	$\Delta\delta$ (″)
24	13	−0.35
30	12	+0.12
35	8	−0.39
44	9	−0.24
57	10	−0.48
68	6	−0.60
78	12	−0.47
84	15	−0.19

Melb. 68.

δ (°)	Wt.	$\Delta\delta$ (″)
24	30	−0.17
30	28	−0.02
37	21	+0.20
42	30	−0.31
48	35	−0.19
55	35	+0.01
62	50	−0.24
70	20	−0.33
79	21	−0.17
85	38	−0.02

Cord. 76.

δ (°)	Wt.	$\Delta\delta$ (″)
23	44	+0.16
27	38	+0.03
31	26	+0.19
37	37	+0.16
43	17	+0.22
47	14	+0.24
52	9	+0.21
58	14	+0.43
65	17	+0.28
73	65	+0.12
82	128	+0.11

Melb. 76.

δ (°)	Wt.	$\Delta\delta$ (″)
24	37	−0.13
28	34	−0.43
36	16	−0.18
46	9	−0.24
57	36	−0.28
67	19	−0.14
76	20	−0.10
82	21	−0.02
86	20	−0.03

Cape 76.

δ (°)	Wt.	$\Delta\delta$ (″)
24	43	−0.04
30	41	−0.05
36	38	−0.20
42	44	−0.11
48	38	+0.13
53	25	+0.08
58	31	+0.22
63	38	+0.28
68	34	+0.31
72	8	−0.21
77	18	+0.73
83	12	+0.83
87	16	+0.27

Cape 84.

δ (°)	Wt.	$\Delta\delta$ (″)
24	51	−0.11
30	37	−0.04
36	19	−0.02
42	22	0.00
48	24	+0.04
55	33	−0.34
62	33	−0.28
74	24	−0.17
85	33	−0.07

Cape 89.

δ (°)	Wt.	$\Delta\delta$ (″)
24	51	+0.11
30	40	+0.16
35	30	−0.02
41	36	+0.09
48	21	−0.13
55	36	0.00
62	17	−0.05
75	21	0.00
85	33	−0.10

DETERMINATION OF FINAL WEIGHTS.

I have used computed weights throughout the work, — a matter which I consider to be of much importance. In computing them, the adopted general principle is that there is a certain part of the probable error, ϵ, of a star-position which diminishes as the reciprocal of the square-root of the number of observations; and that there is another part, ϵ_1, which is found to be constant whenever the positions of

two or more catalogues are compared. The latter represents constant error from whatever source. Given for a certain catalogue a series of discrepancies from an absolute standard, through trial of various ratios, $\frac{\epsilon}{\epsilon_1}$, it is possible with comparatively little trouble to arrive at a value of this ratio such that the probable error of the unit of weight where the numbers of observations are largest for single stars shall be equal to that derived from those stars which have fewest observations. With the ratio $\frac{\epsilon}{\epsilon_1}$ known it is a simple matter to determine ϵ and ϵ_1 from which to construct a system of weights corresponding to any probable error of the unit. The units which I employ are those which correspond to probable errors of $\pm 0^s.03 \sec\delta$ and $\pm 0''.3$ in R.A. and decl., respectively. In Table III, owing to revisions, the weights in a few instances differ somewhat from those which were actually adopted in computing the places of the standard stars herein given. But these differences are unimportant, except in case of Melb. 68 in decl. for which, by inadvertence, weights about 40 per centum greater than those of Table III were employed. After completing the catalogue I tested the unit of weight in a general way, through the observed residuals of 105 stars most frequently observed. These gave for the probable errors of the units of weight, $\pm 0^s.029 \sec\delta$ and $\pm 0''.31$, respectively — thus agreeing almost exactly with the predicted probable errors of the units. That this is no mere accident is shown by the following table which exhibits the deduced probable errors, arranged in groups of ten stars.

Observed P.E. of Units of Weight.

Limits of δ	E_α	E_δ
-22° to -24°	$\pm 0^s.033 \sec\delta$	$\pm 0''.27$
-25 to -30	0.023 "	0.31
-33 to -37	0.032 "	0.30
-38 to -40	0.032 "	0.29
-40 to -43	0.034 "	0.32
-44 to -46	0.027 "	0.27
-47 to -52	0.028 "	0.34
-54 to -61	0.026 "	0.30
-61 to -67	0.030 "	0.34
-68 to -79	± 0.027 "	± 0.35

The errors of the catalogue right-ascensions appear to increase very nearly in proportion to sec δ. The gain in accuracy toward the higher declinations is less than might have been anticipated.

Since there is no absolute standard of star-positions the rigorous determination of weights for each star-catalogue, in the manner I have indicated, involves attention both to the character of the curve of systematic correction and also to the part which each catalogue has in influencing the amount of the residual pertaining to it. I do not, however, offer the weights of Table III as anything more than fair approximations to those which could be derived. Indeed, the matter of weights is entitled to more attention than I could give it on the present occasion. Revision of the system of equatorial stars offers a better opportunity for ascertaining the weights with precision.

Table III. Weights in Right-Ascension.

Wt.	Bradley	Piazzi	Cape 30	S.H. 32	Ms. 35	Cape 33 Cape 37	Cape 52	So. 51	Cape 59	Melb. 62 Melb. 76	Melb. 68	Cord. 76	Cape 76	Cape 84 Cape 89
0.05	. .	3 to 5	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
0.1	1 or 2	6 to 20	1	. .	2 to 4	. .	. .	. .	. .	. .	. .	. .	. .	. .
0.15	. .	21 to 90	. .	1	. .	. .	1	. .	. .	. .	. .	. .	. .	. .
0.2	3 to 5	90+	2	. .	5 to 9	1	. .	1	. .	. .	. .	. .	. .	. .
0.25	. .	. .	. .	. .	. .	. .	2	. .	. .	. .	. .	. .	. .	. .
0.3	6 to 8	. .	3	2	10+	. .	. .	. .	. .	. .	. .	. .	. .	. .
0.4	9 to 11	. .	4	3	. .	2	3	2	1	1	. .	1	1	1
0.5	12 to 14	. .	5	4	. .	. .	4 or 5	3	. .	. .	1	. .	. .	. .
0.6	15 to 21	. .	6	5	. .	3	6	4	. .	. .	. .	. .	. .	. .
0.7	22+	. .	7	6	. .	4	7 to 9	5	2	2	. .	2	2	2
1.0	. .	. .	8 to 16	7 to 12	. .	5 or 6	10+	6 to 11	3	3 or 4	2	3 to 5	3 or 4	3
1.5	. .	. .	17+	13 to 19	. .	7 to 10	. .	12 to 24	4 to 6	5 or 6	3 or 4	6 to 9	5 to 7	4 or 5
2.0	. .	. .	. .	20 to 50	. .	11 to 16	. .	25+	7 to 8	7 to 11	5	10 to 16	8 to 12	6 to 8
2.5	. .	. .	. .	51+	. .	17 to 25	. .	. .	9 to 12	12 to 19	6 or 7	17 to 29	13 to 21	9 to 11
3.0	. .	. .	. .	. .	. .	26+	. .	. .	13 to 19	20+	8 to 11	30+	22+	12 to 17
4.0	. .	. .	. .	. .	. .	. .	. .	. .	20 to 39	. .	12 to 17	. .	. .	18 to 32
5.0	. .	. .	. .	. .	. .	. .	. .	. .	40+	. .	18+	. .	. .	33+

Table III. Weights in Declination.

t.	Bradley	Piazzi	Brisb.	Cape 31	S.H. 31	Cape 33	Ms. 35	Cape 37	Cape 51	So. 51	Cape 59	Melb. 62	Melb. 68	Cord. 76 one pos.	Melb. 76	Cape 76	Cape 84 Cape 89
05	1	4 to 7	2 to 10	. .	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1	2	8 to 16	10+	1 or 2	1 or 2	. .	2 to 4	. .	. .	1	. .	. .	. .	. .	. .	. .	. .
15	3 or 4	16 to 51	. .	. .	. .	1	5 to 9	. .	. .	. .	. .	1	. .	. .	. .	. .	. .
2	5 to 9	52+	. .	3 to 9	3 to 5	. .	10+	1	1	2 or 3	. .	. .	. .	1	. .	. .	. .
3	10 to 29	. .	. .	10+	6 to 11	2	. .	. .	. .	4	1	2	1	. .	1	1	. .
4	30+	. .	. .	. .	12 to 25	. .	. .	2	2	5 to 7	. .	3	. .	2	. .	. .	1
5	. .	. .	. .	. .	26+	3	. .	3	3	7 to 11	2	1	2	3 and 4	. .	. .	. .
6	. .	. .	. .	. .	. .	4	. .	4	4	12 to 19	. .	5	. .	5 and 6	2	2	. .
7	. .	. .	. .	. .	. .	5	. .	5	5	20+	3	6 or 7	3	7 to 10	. .	. .	2
0	. .	. .	. .	. .	. .	6 to 12	. .	6 to 14	6 to 14	. .	4 or 5	8+	4 to 6	11+	3 to 5	3 or 4	3 or 4
5	. .	. .	. .	. .	. .	13+	. .	15+	15+	. .	6 to 8	. .	7 to 11	. .	6 to 9	5 or 6	5 or 6
0	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	9 to 12	. .	12 to 18	. .	10 to 17	7 to 9	7 to 9
5	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	13 to 17	. .	19 to 29	. .	18+	10 to 13	10 to 13
0	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	18+	. .	30+	. .	. .	14+	14+

Opposite the weight will be found in the column devoted to each catalogue the number of observations to which that weight is assigned. For Cordoba 76 in right-ascension the weight is to be computed for each position of the instrument; in declination the weight is to be computed for each year; the weights so computed in case the star has been observed in more than one position, or in more than one year, are to be added in order to obtain the weight of the complete catalogue-position.

For the northern catalogues it was necessary to take into account the diminution of weight with zenith-distance. This I have accomplished after a brief examination of the question by adopting a series of factors with which to multiply the weights. The factor unity for 70° of zenith-distance was adopted both for R.A. and decl. and interpolated to 0.1 at $z = 82°$ for R.A.; and to 0.1 at $z = 80°$ for declination. It is not to be denied, however, that the observations at large zenith-distances are relatively much more accurate at some observatories than they are at others; so that, in a definitive discussion the weights ought not to diminish with the zenith-distance according to the same inflexible law at all observatories alike.

Systematic Corrections — Special Remarks.

The new standard catalogue of 297 southern stars, to which allusion has already been made, afforded the means for a revision of all the systematic corrections except those for Cape 33, Cape 84 and Cape 89. Especial attention was given to Brisb. 25, Madras 35, Cape 51, Cord. 76 and Cape 76, not only because there were some difficulties in relation to those catalogues, but also because they contain the most valuable material for the purposes of general investigation relating to stars south of −20°. It is desirable, however, to be in possession of a still larger catalogue of standard stars in order to ascertain still more accurately the corrections required by these catalogues. This can be effectively brought about only through further observations. The curves of correction have been drawn with careful deliberation. In general, I have preferred to avoid sharp inflexions in these curves, admitting them only when careful analysis of the testimony appeared to warrant it.

There is a singular anomaly in the R.A. curve of Cape 76 at −60°. At −55° I have assumed that the change occurs *per saltum* (a drop of $-0^s.08$); that the correction remains constant at $-0^s.009$ from −55° to −65°; and then that it suddenly changes to $+0^s.050$. Dr. Downing has noticed that there is an abrupt alteration in the relation of the right-ascensions of Gould's and Stone's Catalogues at −55° of declination (*M.N.*, Vol. XLVII, pp. 447 and 452). He shows that "this break cannot be accidental," though he suggests no explanation for it. The right-ascensions of the zone, −55° to −65°, in the Cape Catalogue of Stone are founded almost exclusively on the observations of 1875. A direct comparison for $\Delta\alpha$ between the standard catalogue of 297 stars and the annual volume of the Cape Observatory for 1875, having 41 stars in common within the limits −55° to −65°, results thus: N.S. − Cape 75 = $-0^s.012$. In that year Mr. Stone employed "the galvanic method, and registered [the transits] on a Bond's Spring Governor Chronograph." In other years the transits were observed by the method of eye-and-ear. It thus becomes apparent that the abrupt alteration in the curve of correction is due to differences of personal equation between the two methods as to transits of equatorial stars compared with those of greater declination.

For the right-ascensions of Taylor, Ms. 35, I adopt the correction, $-0^s.061 + 0^s.080\ tg\ \delta$. The comparison between observed and computed corrections is given in the following; wherein the weights are in accordance with Table III of the present communication.

N.S. — Ms. 35 in Right-Ascension.

δ	Wt.	Correction Obs.	C	δ	Wt.	Correction Obs.	C
°		s	s	°		s	s
+55.5	3	+0.059	+0.055	−24.2	7	−0.097	−0.097
+45.8	3	+0.036	+0.021	−29.8	8	−0.102	−0.107
+35.9	4	−0.058	−0.003	−35.0	8	−0.119	−0.117
+24.3	6	−0.032	−0.025	−41.1	10	−0.145	−0.131
+14.8	8	−0.058	−0.039	−47.5	7	−0.137	−0.148
+ 5.6	8	−0.054	−0.053	−53.8	6	−0.148	−0.170
− 5.4	5	−0.098	−0.067	−60.4	5	−0.225	−0.202
−15.2	5	−0.086	−0.083	−67.7	. .	−0.26	−0.256

There seems to be here a high order of excellence in the systematic sense. I suspect that the worst errors in the catalogue-positions of individual stars are due to mistakes in the computations. It is also a great disadvantage not to know the epochs of observation.

Similar remarks apply to the right-ascensions of Piazzi, though the accuracy of individual observations is doubtless very much less than for the observations of Taylor. I adopt as the correction for the right-ascensions of Piazzi, $+0^s.098 + 0^s.138\ tg\ \delta$, which gives a very fair representation of observation from +65° to −45° of declination.

At the end of Table IV, I give the correction in declination for the Cordoba General Catalogue in separate years. In the table the numbers apply to the indiscriminate mean (Lacaille-stars) as I have used it.

In constructing the standard catalogue of 297 stars I did not use the star-places of Lacaille's fundamental catalogue from fear of the large and uncertain systematic errors it might contain. The right-ascensions as revised by Dr. Downing (*M.N.* XLVIII, 322) from Dr. Powalky's memoir in the Report of the U.S. Coast and Geodetic Survey for 1882 were compared with the Normal System of the present standard catalogue, as follows:

N.S. — Lac. 1751 in Right-Ascension.

δ	No. of Stars	$\Delta\alpha_\delta$
°		s
−35	19	−0.10
−44	32	+0.05
−56	28	−0.05
−65	28	−0.32
−76	13	−0.78

The corrected probable error for a single right-ascension appears to be very nearly $\pm 0^s.17 \sec\delta$, and this agrees very well with Dr. Downing's suggestion. This would entitle Lacaille's fundamental right-ascensions to a weight of 0.03 upon the scale of weights adopted in this paper. I have also made a rough comparison of the principal standard stars with the declinations of Dr. Downing's paper.

N.S. — Lac. 1751 (Downing) in Declination.

δ	No. of Stars	$\Delta\delta_\delta$	δ	No. of Stars	$\Delta\delta_\delta$
°		″	°		″
−32	12	+1.3	−59	7	+7.2
−37	11	+2.7	−63	6	+2.2
−42	11	+4.7	−68	4	+1.3
−48	11	+5.2	−77	3	−1.7
−55	9	+5.8			

Lacaille's declinations were obtained with three different instruments.

On pages 487 to 490 of Powalky's memoir (Rept. U.S.C. and G. Survey for 1882) he gives the declinations as he deduced them directly from the observations. Comparing with these declinations we have:

Lacaille's Sector Observations.

δ	No. Stars	N.S.—L.	Formula
°		″	″
−15.3	17	+6.8	+6.8
−24.2	15	+4.7	+4.5
−29.5	15	+3.1	+3.2
−38.5	17	+0.2	+0.9
−44.2	16	−0.5	−0.5
−51.2	19	−1.8	−2.3

I find that the sector observations can be very well represented by the formula of correction, $+0''.25\ (42°.2 + \delta)$ from which the last column of the preceding table is computed. The hypothesis that the error of the sector arises from a uniformly progressive error of graduation from one end of the arc to the other seems to be very strongly supported. At the same time, the probable error of a sector observation appears to be $\pm 1''.8$.

Lacaille's Sextant Observations (Princ. Tel.)

°		″	°		″
− 6	15	+2.8	−59	13	+2.9
−19	6	+3.1	−64	12	−1.6
−34	9	+1.2	−69	11	−2.1
−53	9	+3.7	−77	8	−5.5

I infer that the probable error of a sextant observation ("principal telescope") is about $\pm 2''.0$. There were not sufficient observations with the sextant "attached telescope." to make a research upon them worth while.

Referring again generally to the systematic corrections as exhibited in Table IV it will be noticed that, with one exception, the corrections, $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ are assumed to be of the form, $a \sin\alpha + b \cos\alpha$. Usually this represented the groups of observed residuals with about the degree of accuracy required by the predicted probable errors. This, I think, must be regarded as a very satisfactory test of the adopted form of correction. For Melbourne 1862, however, I have adopted for $\Delta\delta_\alpha$:

$$-0''.01 \sin\alpha - 0''.22 \cos\alpha + 0''.07 \sin 2\alpha + 0''.26 \cos 2\alpha.$$

The observations both north and south of −20° appear to require a correction something like this, which, in this case, represents the groups as well as a hand-curve should be expected to represent them. Comparing the declinations of Greenwich with Melbourne 62, including the stars from 53° to 143° of north polar distance, Gyldén found for Gr. − M (*V.J.S.*, V, 291):

$$-0''.04 \sin\alpha - 0''.07 \cos\alpha + 0''.34 \sin 2\alpha + 0''.40 \cos 2\alpha,$$

which bears a general resemblance to the formula I have adopted.

Table IV. Systematic Corrections in Right-Ascension.

δ	Br. 1755	Pi. 00	Cape 30	S.H. 32	Cape 33	Ms. 35	Cape 37	Cape 52	So. 51	Cape 59	δ
°	s	s	s	s	s	s	s	s	s	s	
+30	−0.084	+0.178	. .	−0.040	+0.017	−0.015	+0.010	. .	+0.024	+0.022	+30
+25	−0.084	+0.163	. .	−0.040	+0.037	−0.024	−0.006	. .	+0.019	+0.022	+25
+20	−0.084	+0.148	. .	−0.040	+0.029	−0.032	−0.012	. .	+0.014	+0.022	+20
+15	−0.084	+0.135	. .	−0.040	+0.022	−0.040	−0.016	. .	+0.010	+0.022	+15
+10	−0.084	+0.123	. .	−0.040	+0.016	−0.047	−0.022	+0.016	+0.005	+0.022	+10
+ 5	−0.084	+0.110	. .	−0.040	+0.012	−0.054	−0.022	+0.016	0.000	+0.022	+ 5
0	−0.083	+0.098	+0.028	−0.040	+0.010	−0.061	−0.020	+0.016	−0.004	+0.023	0
− 5	−0.082	+0.086	+0.023	−0.040	+0.010	−0.068	−0.016	+0.016	−0.009	+0.024	− 5
−10	−0.082	+0.073	+0.027	−0.040	+0.010	−0.075	−0.010	+0.016	−0.014	+0.026	−10
−15	−0.081	+0.061	+0.031	−0.040	+0.010	−0.082	−0.002	+0.016	−0.017	+0.028	−15
−20	−0.080	+0.048	+0.035	−0.040	+0.013	−0.090	+0.004	+0.016	−0.021	+0.030	−20
−25	−0.067	+0.033	+0.039	−0.050	+0.016	−0.098	+0.007	+0.016	−0.026	+0.032	−25
−30	−0.046	+0.018	+0.044	−0.072	+0.022	−0.107	+0.010	+0.011	−0.030	+0.039	−30
−35	. .	+0.001	+0.048	−0.090	+0.024	−0.117	+0.013	−0.041	−0.030	+0.047	−35
−40	. .	−0.018	+0.053	−0.090	+0.026	−0.128	+0.016	−0.052	−0.030	+0.055	−40
−45	. .	−0.040	+0.060	−0.094	+0.027	−0.141	+0.019	−0.067	−0.030	+0.064	−45
−50	. .	. .	+0.072	−0.109	+0.027	−0.156	+0.022	−0.067	−0.030	+0.073	−50
−55	. .	. . .	+0.097	−0.127	+0.027	−0.175	+0.025	−0.027	−0.030	+0.082	−55
−60	. .	. .	+0.123	−0.148	+0.026	−0.200	+0.028	−0.012	−0.030	+0.083	−60
−65	. .	. .	+0.148	−0.174	+0.025	−0.233	+0.036	−0.010	−0.030	+0.083	−65
−70	. .	. .	+0.175	−0.205	+0.023	−0.281	+0.045	−0.008	−0.030	+0.080	−70
−75	. .	. .	+0.200	−0.24	+0.019	. .	+0.051	−0.006	−0.030	+0.060	−75
−80	. .	. .	+0.230	−0.21	+0.015	. .	+0.062	−0.004	−0.030	+0.040	−80
−85	. .	. .	. .	−0.11	+0.010	. .	+0.071	−0.002	−0.030	+0.020	−85
h											h
0	Small and uncertain	Very small	+0.032	−0.015	−0.009	+0.020	−0.008	+0.013	+0.019	+0.010	12
1			+0.040	−0.017	−0.012	+0.020	−0.011	+0.011	+0.014	+0.008	13
2			+0.045	−0.018	−0.014	+0.019	−0.013	+0.008	+0.009	+0.005	14
3			+0.048	−0.018	−0.015	+0.017	−0.015	+0.004	+0.003	+0.003	15
4			+0.047	−0.017	−0.015	+0.014	−0.015	+0.001	−0.004	0.000	16
5			+0.043	−0.014	−0.014	+0.010	−0.015	−0.004	−0.010	−0.003	17
6			+0.036	−0.011	−0.012	+0.005	−0.013	−0.008	−0.015	−0.006	18
7			+0.026	−0.007	−0.009	−0.001	−0.012	−0.011	−0.019	−0.008	19
8			+0.015	−0.002	−0.005	−0.006	−0.007	−0.015	−0.022	−0.010	20
9			+0.003	+0.003	−0.002	−0.011	−0.004	−0.015	−0.024	−0.011	21
10			−0.010	+0.007	+0.002	−0.015	0.000	−0.016	−0.024	−0.011	22
11			−0.021	+0.012	+0.006	−0.018	+0.004	−0.015	−0.022	−0.011	23
12			−0.032	+0.015	+0.009	−0.020	+0.008	−0.013	−0.019	−0.010	24

From 12^h to 24^h $\Delta\alpha_\alpha$ has the opposite sign.

Table IV. Systematic Corrections in Right-Ascension.

δ	Melb. 62	Melb. 68	Cord. 76* E.	Cord. 76* W.	Melb. 76	Cape 76	Cape 84	Cape 89	δ
°	s	s	s	s	s	s	s	s	
+30	+0.047	+0.043	. .	. .	+0.043	+0.048	+0.019	+0.040	+30
+25	+0.047	+0.043	. .	. .	+0.043	+0.045	+0.019	+0.035	+25
+20	+0.047	+0.040	. .	. .	+0.040	+0.041	+0.019	+0.030	+20
+15	+0.047	+0.037	. .	. .	+0.034	+0.039	+0.019	+0.027	+15
+10	+0.047	+0.033	. .	. .	+0.030	+0.036	+0.019	+0.023	+10
+ 5	+0.047	+0.029	. .	. .	+0.027	+0.034	+0.019	+0.020	+ 5
0	+0.047	+0.024	−0.001	+0.014	+0.028	+0.034	+0.019	+0.020	0
− 5	+0.045	+0.019	+0.006	+0.008	+0.032	+0.036	+0.019	+0.020	− 5
−10	+0.042	+0.018	+0.011	+0.006	+0.035	+0.040	+0.019	+0.020	−10
−15	+0.039	+0.017	+0.017	−0.001	+0.040	+0.046	+0.020	+0.021	−15
−20	+0.035	+0.017	+0.017	−0.011	+0.046	+0.051	+0.020	+0.021	−20
−25	+0.032	+0.017	+0.011	−0.024	+0.050	+0.053	+0.020	+0.022	−25
−30	+0.031	+0.017	+0.004	−0.042	+0.050	+0.030	+0.021	+0.024	−30
−35	+0.030	+0.017	−0.006	−0.060	+0.050	+0.027	+0.021	+0.028	−35
−40	+0.026	+0.018	−0.008	−0.064	+0.050	+0.036	+0.021	+0.032	−40
−45	+0.019	+0.020	−0.010	−0.068	+0.050	+0.053	+0.022	+0.035	−45
−50	+0.013	+0.019	−0.012	−0.072	+0.050	+0.068	+0.023	+0.038	−50

* The clamp was E. in 1872, 1875.67 to 1877.0, 1878, 1880, and 1884 ; and W. in other years.

δ	Melb. 62	Melb. 68	Cord. 76 E.	Cord. 76 W.	Melb. 76	Cape 76	Cape 84	Cape 89	δ
°	s	s	s	s	s	s	s	s	°
−55	+0.007	+0.015	−0.016	−0.076	+0.048	+0.068	+0.024	+0.043	−55
−60	+0.006	+0.003	−0.019	−0.079	+0.037	−0.009†	+0.029	+0.051	−60
−65	+0.022	−0.014	−0.021	−0.081	+0.022	+0.050	+0.035	+0.060	−65
−70	+0.050	−0.020	−0.009	−0.069	+0.007	+0.040	+0.041	+0.068	−70
−75	+0.078	−0.020	+0.013	−0.047	−0.012	+0.030	+0.042	+0.061	−75
−80	+0.107	−0.008	+0.046	−0.014	−0.032	+0.020	+0.034	+0.049	−80
−85	+0.135	0.000	+0.081	+0.021	−0.046	+0.010	+0.027	+0.037	−85
h									h
0	+0.007	+0.011	+0.026		+0.019	+0.008	0.000	0.000	12
1	−0.002	+0.002	+0.019		+0.016	+0.005	−0.003	−0.001	13
2	−0.010	−0.005	+0.012		+0.013	+0.001	−0.005	−0.002	14
3	−0.018	−0.013	+0.004		+0.008	−0.002	−0.007	−0.003	15
4	−0.025	−0.020	−0.005		+0.003	−0.006	−0.009	−0.003	16
5	−0.030	−0.025	−0.014		−0.003	−0.009	−0.010	−0.004	17
6	−0.033	−0.029	−0.021		−0.007	−0.011	−0.010	−0.004	18
7	−0.034	−0.031	−0.027		−0.012	−0.013	−0.010	−0.004	19
8	−0.032	−0.031	−0.031		−0.016	−0.014	−0.009	−0.003	20
9	−0.028	−0.029	−0.033		−0.018	−0.014	−0.007	−0.003	21
10	−0.023	−0.024	−0.033		−0.020	−0.012	−0.005	−0.002	22
11	−0.015	−0.018	−0.031		−0.020	−0.011	−0.003	−0.001	23
12	−0.007	−0.011	−0.026		−0.019	−0.008	0.000	0.000	24

† Applicable from −55° to −65°. From 12^h to 24^h $\Delta\alpha_\alpha$ has the opposite sign.

Table IV. Systematic Corrections in Declination.

δ	Br. 1755	Pi. 00	Bb. 25	Cape 31	S.H. 31	Cape 33	Ms. 35	Cape 37	Cape 51	So. 51	Cape 59	δ
°	″	″	″	″	″	″	″	″	″	″	″	°
+30	+1.50	−1.10	. .	. .	+1.30	+0.40	+0.26	−0.26	. .	+0.70	−0.08	+30
+25	+1.50	−1.36	. .	. .	+1.30	+0.50	−0.02	−0.13	. .	+0.80	−0.08	+25
+20	+1.50	−1.62	. .	. .	+1.30	+0.32	−0.32	−0.04	. .	+0.90	−0.10	+20
+15	+1.50	−1.62	. .	. .	+1.30	+0.05	−0.56	+0.06	. .	+0.99	−0.12	+15
+10	+1.50	−1.35	. .	+0.14	+1.28	−0.08	−0.68	+0.17	. .	+1.07	−0.16	+10
+ 5	+1.50	−1.29	. .	+0.36	+1.22	−0.10	−0.67	+0.27	. .	+1.13	−0.20	+ 5
0	+1.50	−1.56	+0.4	+0.44	+1.17	−0.08	−0.61	+0.38	−0.24	+1.16	−0.20	0
− 5	+1.50	−1.86	+0.4	+0.44	+1.09	0.00	−0.57	+0.40	−0.22	+1.14	−0.18	− 5
−10	+1.50	−1.96	+0.4	+0.32	+0.96	+0.12	−0.50	+0.40	−0.13	+1.11	−0.13	−10
−15	+1.50	−1.82	+0.4	+0.16	+0.66	+0.42	−0.50	+0.40	+0.02	+1.04	−0.06	−15
−20	+1.50	−1.50	+0.5	+0.10	+0.26	+0.78	−0.45	+0.37	+0.16	+0.94	0.00	−20
−25	+1.50	−1.04	+0.5	+0.10	−0.05	+0.90	−0.34	+0.34	+0.20	+0.85	+0.06	−25
−30	+1.08	−0.50	+0.36	+0.10	+0.01	+0.86	−0.12	+0.26	+0.15	+0.75	+0.10	−30
−35	[0.00]	−1.39	+0.17	+0.13	+0.50	+0.80	+0.25	+0.18	+0.10	+0.70	+0.07	−35
−40	. .	−1.80	+0.13	+0.26	+1.02	+0.63	+0.53	+0.09	+0.14	+0.70	+0.07	−40
−45	. .	−1.60	+0.65	+0.30	+0.98	+0.43	+0.52	+0.02	+0.06	+0.70	+0.11	−45
−50	. .	. .	+1.10	+0.26	+0.85	+0.36	+0.46	−0.05	−0.12	+0.70	+0.17	−50
−55	. .	. .	+1.10	+0.23	+0.73	+0.32	+0.42	−0.11	−0.17	+0.70	+0.22	−55
−60	. .	. .	+1.40	+0.19	+0.71	+0.28	+0.4	−0.17	+0.11	+0.63	+0.22	−60
−65	. .	. .	+1.74	+0.15	+0.81	+0.24	+0.4	−0.19	+0.12	+0.56	+0.22	−65
−70	. .	. .	+1.45	+0.12	+0.88	+0.20	+0.4	−0.15	−0.10	+0.49	+0.22	−70
−75	. .	. .	+0.91	+0.09	+0.76	+0.15	. .	−0.12	−0.21	+0.42	+0.17	−75
−80	. .	. .	+0.60	+0.06	+0.49	+0.10	. .	−0.08	−0.28	+0.35	+0.11	−80
−85	. .	. .	+0.30	. .	+0.19	+0.05	. .	−0.04	−0.28	. .	+0.06	−85
h												h
0	Small and uncertain	−0.18	−0.07	+0.08	+0.50	−0.09	−0.23	−0.10	−0.06	−0.08	−0.02	12
1		−0.04	+0.06	+0.13	+0.45	−0.09	−0.23	−0.09	−0.08	−0.01	0.00	13
2		+0.11	+0.19	+0.18	+0.37	−0.08	−0.22	−0.07	−0.10	+0.06	+0.02	14
3		+0.25	+0.30	+0.21	+0.27	−0.06	−0.19	−0.05	−0.11	+0.12	+0.04	15
4		+0.37	+0.40	+0.23	+0.15	−0.04	−0.15	−0.02	−0.12	+0.18	+0.05	16
5		+0.46	+0.46	+0.23	+0.02	−0.02	−0.10	0.00	−0.11	+0.22	+0.06	17
6		+0.53	+0.50	+0.22	−0.12	0.00	−0.05	+0.03	−0.10	+0.25	+0.07	18
7		+0.56	+0.50	+0.19	−0.24	+0.02	+0.01	+0.06	−0.08	+0.26	+0.07	19
8		+0.55	+0.47	+0.15	−0.35	+0.04	+0.07	+0.08	−0.06	+0.26	+0.07	20
9		+0.50	+0.40	+0.10	−0.43	+0.06	+0.13	+0.09	−0.03	+0.23	+0.06	21
10		+0.42	+0.31	+0.04	−0.49	+0.08	+0.17	+0.10	0.00	+0.19	+0.05	22
11		+0.31	+0.19	−0.02	−0.51	+0.09	+0.21	+0.10	+0.03	+0.14	+0.04	23
12		+0.18	+0.07	−0.08	−0.50	+0.09	+0.23	+0.10	+0.06	+0.08	+0.02	24

From 12^h to 24^h $\Delta\delta_\alpha$ has the opposite sign.

TABLE IV. SYSTEMATIC CORRECTIONS IN DECLINATION.

δ	Melb. 62*		Melb. 68	Cord. 76†	Melb. 76	Cape 76	Cape 84	Cape 89	δ
°	"		"	"	"	"	"	"	
+30	+0.55		+0.11	. .	+0.16	−0.20	−0.53	−0.74	+30
+25	+0.45		−0.08	. .	−0.07	−0.20	−0.34	−0.71	+25
+20	+0.33		−0.15	. .	−0.22	−0.20	−0.27	−0.68	+20
+15	+0.30		−0.15	. .	−0.30	−0.18	−0.25	−0.64	+15
+10	+0.40		−0.15	. .	−0.33	−0.14	−0.25	−0.61	+10
+ 5	+0.68		−0.15	. .	−0.33	−0.10	−0.26	−0.58	+ 5
0	+0.88		−0.16	−0.50	−0.33	−0.05	−0.27	−0.55	0
− 5	+0.93		−0.18	−0.48	−0.33	−0.02	−0.29	−0.52	− 5
−10	+0.81		−0.24	−0.45	−0.36	−0.04	−0.30	−0.49	−10
−15	+0.70		−0.31	−0.41	−0.42	−0.09	−0.30	−0.45	−15
−20	+0.61		−0.32	−0.36	−0.53	−0.13	−0.29	−0.41	−20
−25	+0.51		−0.34	−0.30	−0.63	−0.16	−0.27	−0.36	−25
−30	+0.41		−0.29	−0.24	−0.66	−0.19	−0.25	−0.32	−30
−35	+0.30		−0.24	−0.19	−0.64	−0.20	−0.21	−0.27	−35
−40	+0.20		−0.37	−0.14	−0.62	−0.18	−0.16	−0.24	−40
−45	+0.10		−0.40	−0.08	−0.59	−0.08	−0.18	−0.24	−45
−50	0.00		−0.37	−0.02	−0.56	+0.02	−0.26	−0.24	−50
−55	−0.10		−0.34	+0.03	−0.53	+0.09	−0.33	−0.23	−55
−60	−0.20		−0.37	+0.07	−0.48	+0.16	−0.36	−0.20	−60
−65	−0.30		−0.40	+0.06	−0.41	+0.24	−0.36	−0.18	−65
−70	−0.33		−0.40	+0.03	−0.32	+0.30	−0.30	−0.15	−70
−75	−0.34		−0.31	0.00	−0.25	+0.44	−0.23	−0.11	−75
−80	−0.31		−0.21	0.00	−0.15	+0.56	−0.15	−0.08	−80
−85	−0.16		−0.10	0.00	−0.08	+0.54	−0.08	−0.04	−85
	0^h	12^h							
h	"	"	"	"	"	"	"	"	h
0	+0.04	+0.48	−0.07	+0.02	−0.04	+0.07	+0.09	0.00	12
1	+0.04	+0.47	−0.06	−0.01	−0.05	+0.07	+0.08	−0.02	13
2	−0.01	+0.38	−0.05	−0.04	−0.06	+0.06	+0.07	−0.04	14
3	−0.09	+0.23	−0.03	−0.06	−0.06	+0.05	+0.05	−0.05	15
4	−0.19	+0.06	−0.01	−0.08	−0.06	+0.04	+0.03	−0.06	16
5	−0.26	−0.12	+0.01	−0.10	−0.06	+0.02	0.00	−0.07	17
6	−0.27	−0.24	+0.03	−0.11	−0.05	0.00	−0.02	−0.07	18
7	−0.21	−0.30	+0.04	−0.11	−0.04	−0.02	−0.04	−0.07	19
8	−0.09	−0.29	+0.06	−0.10	−0.02	−0.04	−0.06	−0.06	20
9	+0.08	−0.21	+0.07	−0.09	−0.01	−0.05	−0.08	−0.05	21
10	+0.25	−0.11	+0.07	−0.07	+0.01	−0.06	−0.09	−0.04	22
11	+0.40	−0.02	+0.08	−0.05	+0.03	−0.07	−0.09	−0.02	23
12	+0.48	+0.04	+0.07	−0.02	+0.04	−0.07	−0.09	0.00	24

Except for Melb. 62, from 12^h to 24^h $\Delta\delta_a$ has the opposite sign.

* This is additional to the correction at p. XXII of the Catalogue.

† Applicable to indiscriminate mean. Substitute, with advantage, correction for separate years.

TABLE IV. SYSTEMATIC CORRECTION OF CORDOBA G.C., 1875, IN DECLINATION.

δ	1872	1873	1874.0 to 1875.67	1875.67 to 1877.0	1877	1878	1879	1880	1881	1882	δ
°	"	"	"	"	"	"	"	"	"	"	
+25	−0.17	−0.87	−0.90	−0.40	−1.00	−1.30	−1.33	−0.72	. .	. .	+25
+20	−0.08	−0.80	−0.80	−0.33	−0.86	−1.27	−1.22	−0.48	. .	. .	+20
+15	+0.01	−0.73	−0.70	−0.26	−0.77	−1.22	−1.10	−0.25	. .	. .	+15
+10	+0.09	−0.66	−0.60	−0.20	−0.69	−1.15	−1.03	−0.10	. .	. .	+10
+ 5	+0.18	−0.59	−0.60	−0.14	−0.65	−1.04	−0.98	−0.04	. .	. .	+ 5
0	+0.27	−0.54	−0.60	−0.13	−0.70	−0.93	−0.96	0.00	. .	. .	0
− 5	+0.35	−0.53	−0.60	−0.18	−0.76	−0.79	−0.92	0.00	. .	. .	− 5
−10	+0.43	−0.51	−0.60	−0.22	−0.78	−0.62	−0.87	0.00	. .	. .	−10
−15	+0.51	−0.50	−0.49	−0.26	−0.80	−0.51	−0.80	0.00	. .	. .	−15
−20	+0.59	−0.48	−0.37	−0.29	−0.80	−0.42	−0.67	0.00	. .	. .	−20
−25	+0.60	−0.47	−0.28	−0.30	−0.80	−0.40	−0.56	0.00	+0.50	+0.66	−25
−30	+0.46	−0.45	−0.25	−0.20	−0.77	−0.40	−0.51	0.00	+0.36	+0.66	−30
−35	+0.31	−0.40	−0.22	−0.04	−0.63	−0.41	−0.46	0.00	+0.21	+0.64	−35
−40	+0.28	−0.36	−0.18	+0.08	−0.49	−0.43	−0.39	0.00	+0.01	+0.59	−40

	1872	1873	1874.0 to 1875.67	1875.67 to 1877.0	1877	1878	1879	1880	1881	1882	δ
°	″	″	″	″	″	″	″	″	″	″	°
−45	+0.26	−0.32	−0.09	+0.10	−0.40	−0.47	−0.28	0.00	−0.18	+0.54	−45
−50	+0.23	−0.27	+0.01	+0.07	−0.30	−0.50	−0.16	0.00	−0.20	+0.47	−50
−55	+0.21	−0.22	+0.09	+0.07	−0.20	−0.48	−0.06	0.00	−0.20	+0.40	−55
−60	+0.18	−0.18	+0.10	+0.14	−0.12	−0.46	−0.03	0.00	−0.20	+0.32	−60
−65	+0.15	−0.13	+0.09	+0.14	−0.06	−0.38	0.00	0.00	−0.20	+0.30	−65
−70	+0.12	−0.10	+0.08	+0.11	0.00	−0.30	0.00	0.00	−0.20	+0.30	−70
−75	+0.09	−0.07	+0.06	+0.08	0.00	−0.23	0.00	0.00	. .	. .	−75
−80	+0.06	−0.04	+0.04	+0.06	0.00	−0.15	0.00	0.00	. .	. .	−80
−85	+0.03	−0.02	+0.02	+0.03	0.00	−0.07	0.00	0.00	. .	. .	−85
0h	Uncertain	+0.11	+0.16	−0.14	−0.06	−0.17	+0.01	+0.39			12h
1		+0.04	+0.19	−0.13	−0.10	−0.25	−0.03	+0.29			13
2		−0.03	+0.20	−0.12	−0.13	−0.32	−0.06	+0.17			14
3		−0.11	+0.20	−0.09	−0.16	−0.36	−0.09	+0.03			15
4		−0.17	+0.19	−0.06	−0.17	−0.38	−0.12	−0.10			16
5		−0.22	+0.16	−0.02	−0.18	−0.37	−0.13	−0.23			17
6		−0.26	+0.12	+0.02	−0.17	−0.34	−0.14	−0.34			18
7		−0.28	+0.08	+0.05	−0.15	−0.28	−0.14	−0.43			19
8		−0.28	+0.02	+0.08	−0.12	−0.21	−0.12	−0.50			20
9		−0.26	−0.03	+0.11	−0.08	−0.12	−0.10	−0.52			21
10		−0.23	−0.08	+0.13	−0.04	−0.02	−0.07	−0.51			22
11		−0.18	−0.13	+0.14	+0.01	+0.08	−0.04	−0.47			23
12		−0.11	−0.16	+0.14	+0.06	+0.17	−0.01	−0.39			24

The Standard Catalogue.

In the Catalogue of Southern Standard Stars which follows at the end of this article I have introduced some features not ordinarily found in connection with similar publications. In the columns immediately following the right-ascensions and declinations for 1900 are to be found the computed weights of those quantities. The probable error of the unit of weight for R.A. is $\pm 0^s.03 \sec\delta$. and for declination, $\pm 0''.3$. In the columns next after the annual variations are to be found the weights of ten times the annual variations, — *i.e.* of the annual variation for ten years. Thus the weights of the centennial variations are found by dividing those numbers by 100. In the last four columns of the catalogue are given, respectively: The epoch at which the right-ascension is supposed to be independent of an error in the adopted annual variation; in the next column is given the weight at that epoch; in the next two columns are the corresponding quantities for declination. Thus we have the means for computing the weight of a catalogue-position at any epoch. To avoid misunderstanding I append a practical illustration of the meaning of these quantities. The epoch of the right-ascension of ε *Phœnicis* (No. 1) is 1869, and the weight of R.A. at that epoch is 12. The weight of the decennial variation is 45. Up to 1900 3.1 decades elapse and the weight of the variation from 1869 to 1900 is, therefore, $\frac{45}{(3.1)^2} = 4.68$. Obviously, then, the weight in right-ascension for 1900 is $\frac{4.68\times 12}{4.68+12} = 3.4$. This is also the weight of the right-ascension of this star for 1838, and corresponds to a probable error of $\pm 0^s.016 \sec\delta = \pm 0^s.024$.

All the catalogue-positions are the result of careful solution by least-squares; and in computing the weights given in the catalogue it was considered best to take these as they resulted from the normal equations, and without reference to the special probable error deduced for each particular star.

The proper motions are given for the epoch 1900. Following the proper motions is a column giving the variations of the proper motions for a century in units of the fourth decimal place for R.A. and of the third decimal for declination. For example: The proper motion in right-ascension of β *Hydri* for 1900 is $+0^s.7024$ and its centennial variation is $-0^s.0321$; so that the proper motion for 1840 was $+0^s.7217$.

The positions of α *Centauri* and α *Crucis* are not found in this catalogue. Each is deserving of continued observation; but the predicted place of each must be the subject of more careful attention than is practicable in a work of this kind. It is very doubtful whether the older observations of α *Crucis* are entitled to much confidence,—especially in right-ascension. The effect of the comparatively close and bright components of that star, as seen in small telescopes, must be very confusing as to transits.

As previously explained, the catalogue at the end of this paper is part of a larger catalogue of 297 stars computed to serve as a basis for the accurate determination of systematic corrections, not only for published observations generally, but also for the differential observations in progress here within the belt of sky bounded by the parallels of declination, −22° to −37°. The criterion of selection for the 179 stars of this communication is that the weight of the right-ascension for 1900 shall be not less than 3.0.

COMPARISON WITH NEWCOMB'S NEW STANDARD CATALOGUE.

I have compared the standard catalogue of 297 stars, N.S., with Professor NEWCOMB's catalogue, N, in the *American Ephemeris* for 1900. There are only 3 stars in Professor NEWCOMB's list which are to be found between $-31°$ to $-57°$, and none between $-34°$ and $-47°$.

N.S. — N.

δ	$\Delta\alpha$	$\Delta\mu$	$\Delta\delta$	$\Delta\mu'$	No. of Stars
°	s	s	″	″	
−23	−0.021	−0.0003	−0.32	−0.004	8
−29	−0.019	−0.0003	−0.15	+0.001	12
−58	+0.006	+0.0004	−0.05	−0.003	7
−70	+0.025	+0.0015	−0.22	−0.011	9
−79	+0.013	+0.0006	+0.09	+0.004	10
−84	+0.135	+0.0036	+0.21	−0.003	7

COMPARISON WITH THE CATALOGUE OF DR. AUWERS.

There are 229 stars in common with this work and that of Dr. AUWERS in *A.N.* 3431–32.

N.S. — A. $\Delta\alpha_\delta$ etc.

Decl. limits	No. Stars	$\Delta\alpha$	$\Delta\mu$	$\Delta\delta$	$\Delta\mu'$
° °		s	s	″	″
−20 to −25	16	+0.008	+0.0006	−0.26	−0.006
25 to 30	23	0.019	0.0010	0.22	0.004
30 to 35	23	0.021	0.0009	0.20	0.008
35 to 40	21	0.025	0.0012	0.02	0.001
40 to 45	26	0.034	0.0011	0.30	0.010
45 to 50	24	0.027	0.0008	0.12	0.008
50 to 55	17	0.039	0.0012	0.17	0.006
55 to 60	20	0.023	0.0012	0.30	0.011
60 to 65	16	0.021	0.0013	−0.10	0.007
65 to 70	18	0.024	0.0016	+0.04	0.002
70 to 75	7	0.041	0.0015	0.12	0.002
75 to 80	10	0.022	+0.0022	+0.33*	0.000
−80 to −89	8	+0.086	0.000	0.00	−0.004

* +0″.25 if the declination of *α Apodis* be rejected.

After correcting for differences of the form $\Delta\alpha_\delta$, &c., the outstanding differences were arranged in order of right-ascension. The right-ascensions and their motions were separated into two general sections; $-20°$ to $-45°$ and $-45°$ to $-70°$. It was found that the law of $\Delta\alpha_a$ and $\Delta\mu_a$ is not materially different for these two sections, and they were consolidated. The group of higher declination received one-half the computed weight. Following is a summary.

N.S. — A. $\Delta\alpha_a$, etc.

R.A.	No. Stars α δ	$\Delta\alpha_a$	$\Delta\mu_a$	$\Delta\delta_a$	$\Delta\mu'_a$
h		s	s	″	″
1	14–15	+0.019	+0.0008	+0.18	+0.005
3	16–18	0.011	0.0004	+0.02	+0.001
5	16–17	+0.006	+0.0001	−0.05	−0.004
7	20–21	−0.001	−0.0001	0.04	0.002
9	18–19	+0.001	0.0003	0.01	0.001
11	11–15	−0.013	0.0004	0.17	0.008
13	17–20	0.010	−0.0002	−0.07	−0.001
15	20–21	0.003	+0.0001	+0.12	+0.005
17	30–31	−0.010	0.0001	−0.11	−0.002
19	15–17	+0.005	+0.0002	0.00	+0.002
21	11–11	0.002	0.0000	+0.06	−0.001
23	16–16	+0.006	0.0000	+0.10	+0.004

The concluded systematic differences are given in the next following statement. Adding them to the corresponding quantities of Dr. AUWERS, there should be systematic harmony with the results of the present paper.

DEDUCED SYSTEMATIC CORRECTIONS, N.S. — A.

δ	$\Delta\alpha_\delta$ 1830	$\Delta\alpha_\delta$ 1900	$\Delta\mu_\delta$	$\Delta\delta_\delta$ 1830	$\Delta\delta_\delta$ 1900	$\Delta\mu'_\delta$
°	s	s	s	″	″	″
−20	−0.038	+0.010	+0.0007	+0.16	−0.26	−0.006
25	0.041	0.014	0.0008	0.15	0.24	0.006
30	0.044	0.020	0.0009	0.15	0.20	0.005
35	0.045	0.025	0.0010	0.14	0.14	0.004
40	0.043	0.029	0.0010	0.23	0.16	0.006
45	0.041	0.031	0.0010	0.36	0.17	0.008
50	0.043	0.031	0.0010	0.45	0.14	0.008
55	0.050	0.028	0.0011	0.37	0.20	0.008
60	0.062	0.024	0.0012	0.37	0.16	0.008
65	0.074	0.023	0.0014	0.30	−0.05	0.005
70	0.083	0.026	0.0016	0.23	+0.06	0.002
75	0.093	0.027	0.0017	0.19	0.12	−0.001
80	−0.103	+0.029	+0.0019	0.12	0.12	0.000
−85	. .	. .	. .	+0.06	+0.06	0.000

$$\Delta\alpha_a = +0\overset{s}{.}003 \sin\alpha \quad +0\overset{s}{.}010 \cos\alpha$$
$$\Delta\mu_a = -0.0000 \sin\alpha \quad +0.0003 \cos\alpha$$
$$\Delta\delta_a = -0\overset{\prime\prime}{.}02 \sin\alpha \quad +0\overset{\prime\prime}{.}09 \cos\alpha$$
$$\Delta\mu'_a = -0.002 \sin\alpha \quad +0.002 \cos\alpha$$

Several of the individual differences N.S. — N. are larger than one would have expected from different methods of treatment. Much the largest is for *γ Sagittarii*; N.S. — N $= +1''.92$; N.S. — A $= -0''.22$. The next largest is that for *β Octantis*; N.S. — N $= +1''.05$.

Following are large differences between the positions of Dr. AUWERS and my own.

INDIVIDUAL DIFFERENCES: N.S. — A.

Star	$\Delta\alpha$	$\Delta\mu$	$\Delta\delta$	$\Delta\mu'$
	s	s	″	″
ψ Phœnicis	. .	. .	+0.70	+0.031
θ Eridani	+0.119	+0.0026	. .	. .
Br. 590	−0.054	−0.0006	. .	. .
L. 3259	+0.092	+0.0026	. .	. .
L. 1212	. .	. .	−0.94	−0.033
ω Carinae	−0.140	−0.0035	. .	. .
α Apodis	. .	. .	+1.20	+0.023
χ Lupi	−0.070	−0.0009	. .	. .
λ Pavonis	. .	. .	+0.89	+0.028

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No.	Name	Mag.	R.A. 1900	Wt.	An. Var.	Wt./100	$\frac{d^2\alpha}{dt^2}$	Prec.	μ	$\Delta\mu$
			h m s		s		s	s	s	
1	ε Phoenicis	3.8	0 4 20.216	3	+ 3.0563	45	− 0.0287	+ 3.0462	+0.0101	
2	L 9756	5.6	5 30.278	5	2.8012	47	0.1918	2.8192	−0.0181	+ 14
3	ζ Tucanae	4.1	14 51.758	4	3.1555	51	0.0661	2.8830	+0.2725	− 62
4	β Hydri	2.7	20 30.058	11	3.2220	152	0.1481	2.5196	+0.7024	−321
5	α Phoenicis	2.4	21 20.501	3	2.9740	58	0.0228	2.9574	+0.0166	− 3
6	β¹ Tucanae	4.3	26 57.673	4	+ 2.7675	55	− 0.0442	+ 2.7579	+0.0096	− 2
7	μ Phoenicis	4.7	36 36.040	4	2.8438	21	0.0226	2.8476	−0.0038	
8	α Sculptoris	4.2	53 47.234	5	2.8933	75	0.0098	2.8940	−0.0007	
9	β Phoenicis	3.3	1 1 37.269	5	2.6830	80	0.0179	2.6885	−0.0055	
10	ζ Phoenicis	4.2	4 10.967	4	2.5303	56	0.0216	2.5294	+0.0009	
11	γ Phoenicis	3.4	24 1.383	4	+ 2.6095	78	− 0.0125	+ 2.6127	−0.0032	
12	α Eridani	1.0	33 59.438	9	2.2394	150	0.0129	2.2282	+0.0112	− 2
13	ε Sculptoris	5.4	40 57.736	4	2.8111	53	0.0037	2.8002	+0.0109	
14	χ Eridani	3.9	52 3.971	4	2.3377	55	0.0096	2.2659	+0.0718	− 6
15	α Hydri	2.9	55 37.082	5	1.8897	70	0.0034	1.8546	+0.0351	− 5
16	φ Eridani	3.5	2 12 56.185	3	+ 2.1443	53	− 0.0042	+ 2.1358	+0.0085	
17	κ Fornacis	5.4	17 57.962	3	2.7443	21	− 0.0007	2.7314	+0.0129	
18	δ Hydri	4.1	19 58.077	3	1.0540	48	+ 0.0290	1.0637	−0.0097	+ 2
19	θ¹ Eridani	3.7	54 28.191	3	2.2743	45	− 0.0001	2.2794	−0.0051	
20	Br 434	4.1	57 58.965	4	2.6445	60	+ 0.0017	2.6552	−0.0107	
21	θ Hydri	5.8	3 2 2.792	6	+ 0.0916	64	+ 0.0713	+ 0.0857	+0.0059	
22	α Fornacis	3.6	7 49.342	5	2.5460	82	0.0019	2.5226	+0.0234	+ 3
23	Br 469	3.4	15 4.060	5	2.6671	78	+ 0.0027	2.6641	+0.0030	
24	L 1060	4.4	15 56.029	4	2.3933	32	− 0.0004	2.1171	+0.2762	− 12
25	Br 495	4.5	29 22.213	5	2.6485	103	+ 0.0030	2.6458	+0.0027	
26	Br 530	3.9	42 32.693	5	+ 2.5791	76	+ 0.0026	+ 2.5918	−0.0127	− 3
27	L 1248	4.1	45 42.709	3	+ 2.2444	34	0.0025	+ 2.2485	−0.0041	
28	γ Hydri	3.2	48 47.072	10	− 0.9793	119	0.1071	− 0.9915	+0.0122	− 2
29	δ Reticuli	4.7	57 9.623	3	+ 0.9389	57	0.0195	+ 0.9397	−0.0008	
30	δ Mensae	5.8	4 24 43.862	3	− 4.1875	23	0.2796	− 4.1951	+0.0076	+ 12
31	α Doradus	3.1	31 50.128	4	+ 1.2932	68	+ 0.0098	+ 1.2864	+0.0068	
32	ε Leporis	3.1	5 1 13.648	6	2.5388	73	0.0032	2.5370	+0.0018	
33	α Columbae	2.5	36 1.656	10	2.1714	151	0.0027	2.1716	−0.0002	
34	γ Columbae	4.5	53 59.481	3	2.1261	53	0.0024	2.1267	−0.0006	
35	κ Columbae	4.8	6 12 59.660	3	2.1337	49	0.0022	2.1345	−0.0008	
36	ζ Can. Maj.	3.2	16 28.435	5	+ 2.3023	88	+ 0.0019	+ 2.3023	0.0000	
37	α Carinae	0.4	21 43.886	10	1.3309	156	0.0009	1.3295	+0.0014	
38	Br 972	4.8	30 51.868	5	2.5140	71	0.0015	2.5136	+0.0004	
39	ν Puppis	3.5	34 42.124	4	1.8362	73	0.0014	1.8357	+0.0005	
40	κ Can. Maj.	4.0	46 6.343	4	2.2407	68	0.0014	2.2417	−0.0010	
41	α Pictoris	3.5	47 9.889	3	+ 0.6179	53	− 0.0050	+ 0.6287	−0.0108	+ 7
42	τ Puppis	3.2	47 27.294	3	+ 1.4889	35	0.0006	+ 1.4860	+0.0029	
43	ζ Mensae	5.8	48 22.345	4	− 4.9208	33	− 0.1540	− 4.9168	−0.0040	+ 20
44	ε Can. Maj.	1.8	54 41.722	11	+ 2.3575	138	+ 0.0013	+ 2.3576	−0.0001	
45	σ Can. Maj.	3.6	57 44.094	3	+ 2.3891	68	+ 0.0012	+ 2.3904	−0.0013	
46	δ Can. Maj.	2.1	7 4 19.507	8	+ 2.4392	103	+ 0.0011	+ 2.4397	−0.0005	
47	π Puppis	2.7	13 36.648	4	+ 2.1184	76	+ 0.0011	+ 2.1197	−0.0013	
48	δ Volantis	4.1	16 52.936	3	− 0.0160	46	− 0.0252	− 0.0164	+0.0004	
49	η Can. Maj.	2.9	20 8.398	5	+ 2.3729	90	+ 0.0011	+ 2.3735	−0.0006	
50	σ Puppis	3.5	26 3.496	3	+ 1.9025	49	+ 0.0008	+ 1.9088	−0.0063	+ 2
51	Br 1120	4.2	39 47.590	4	+ 2.4074	49	+ 0.0011	+ 2.4087	−0.0013	
52	L 2958	3.6	41 41.483	3	+ 2.1362	38	+ 0.0012	+ 2.1387	−0.0025	
53	L 3911	7.8	53 1.877	7	−44.2397	98	−16.8841	−44.2137	−0.0260	+ 53
54	χ Carinae	3.7	54 14.150	5	+ 1.5260	74	− 0.0030	+ 1.5306	−0.0046	
55	ζ Puppis	2.5	8 0 4.176	4	+ 2.1079	70	+ 0.0013	+ 2.1110	−0.0031	
56	ρ Puppis	3.2	3 17.096	10	+ 2.5541	109	+ 0.0010	+ 2.5612	−0.0071	
57	γ Velorum	3.0	6 27.075	4	− 1.8497	79	0.0000	1.8501	−0.0004	
58	L 3259	4.7	14 48.675	3	+ 2.2434	59	+ 0.0020	2.2543	−0.0109	
59	ε Carinae	2.1	20 27.754	5	+ 1.2362	97	− 0.0087	+ 1.2393	−0.0031	
60	θ Chamael.	4.7	23 38.571	4	− 1.7246	30	− 0.1650	− 1.6782	−0.0464	− 10

No.	Decl. 1900	Wt.	An. Var.	Wt. 100	$\frac{d^2\delta}{dt^2}$	Prec.	μ'	$\Delta\mu'$	Ep.$_\alpha$	Wt. at Ep.	Ep.$_\delta$	Wt. at Ep.
	° ′ ″		″		″	″	″					
1	−46 17 57.49	3	+19.839	29	−0.017	+20.048	−0.209	. .	69	12	72	10
2	82 46 48.35	5	20.025	67	0.018	20.046	−0.021	0	73	31	69	23
3	65 27 45.10	3	21.158	29	0.038	20.010	+1.148	0	71	15	75	12
4	77 49 2.68	6	20.288	84	0.049	19.972	+0.316	+ 2	67	53	67	27
5	42 50 56.78	3	19.555	48	0.049	19.965	−0.410	0	64	12	63	10
6	−63 30 32.91	3	+19.851	35	−0.058	+19.913	−0.062	0	67	15	73	11
7	46 38 3.08	3	19.755	21	0.075	19.797	−0.042	. .	76	10	77	9
8	29 53 52.78	3	19.489	37	0.106	19.502	−0.013	. .	67	16	71	11
9	47 15 15.86	3	19.303	36	0.112	19.332	−0.029	. .	65	18	71	13
10	55 46 49.61	3	19.278	29	0.110	19.271	+0.007	. .	66	13	73	10
11	−43 49 50.18	3	+18.491	55	−0.141	+18.719	−0.228	. .	62	14	66	12
12	57 44 41.17	5	18.343	81	0.139	18.389	−0.046	− 1	65	38	66	22
13	25 33 8.49	3	18.075	23	0.183	18.138	−0.063	. .	69	12	77	10
14	52 6 24.17	3	17.971	24	0.172	17.702	+0.269	− 5	68	12	76	9
15	62 3 23.24	4	17.571	58	0.143	17.554	+0.017	− 2	65	21	65	15
16	−51 58 30.54	3	+16.727	38	−0.178	+16.772	−0.045	. .	66	13	70	11
17	24 16 14.38	3	16.462	23	0.235	16.527	−0.065	. .	79	12	78	10
18	69 6 52.52	3	16.422	33	0.094	16.427	−0.005	+ 1	66	15	70	10
19	40 42 19.02	3	14.538	43	0.234	14.547	+0.021	. .	67	12	65	11
20	24 0 59.10	3	14.251	48	0.275	14.303	−0.052	. .	69	10	71	9
21	−72 17 34.94	5	+14.058	40	−0.016	+14.052	+0.006	. .	70	26	74	19
22	29 22 52.10	4	14.339	45	0.280	13.687	+0.652	− 3	66	15	72	12
23	22 7 18.19	3	13.254	42	0.298	13.217	+0.037	. .	69	13	65	9
24	43 27 8.63	4	13.895	37	0.295	13.160	+0.735	−26	74	14	73	13
25	21 58 5.61	3	12.219	51	0.310	12.251	−0.032	. .	62	13	70	8
26	−23 32 42.43	5	+10.783	44	−0.314	+11.318	−0.535	+ 1	68	12	76	10
27	36 30 11.29	3	11.030	24	−0.277	11.089	−0.059	. .	71	12	75	10
28	74 32 44.01	5	10.971	64	+0.114	10.864	+0.107	− 2	69	46	69	24
29	61 40 57.75	2	10.205	29	−0.122	10.240	−0.035	. .	62	12	70	8
30	80 26 53.65	3	8.160	22	+0.554	8.098	+0.062	− 1	76	21	75	15
31	−55 15 6.15	3	+ 7.510	43	−0.179	+ 7.525	−0.015	. .	62	14	66	11
32	22 30 19.12	5	5.006	49	0.360	5.086	−0.080	. .	68	25	72	18
33	34 7 38.78	5	2.049	73	0.316	2.093	−0.044	. .	66	48	67	25
34	35 17 38.20	3	+ 0.525	40	0.310	+ 0.526	−0.001	. .	65	12	67	9
35	35 6 25.80	3	− 1.063	41	0.310	− 1.136	+0.073	. .	66	13	68	10
36	−30 1 8.30	4	− 1.444	58	−0.334	− 1.440	−0.004	. .	62	18	68	13
37	52 38 27.91	5	1.899	81	0.193	1.899	0.000	. .	65	42	66	23
38	22 53 7.71	4	2.680	48	0.362	2.692	+0.012	. .	69	12	76	9
39	43 6 30.01	4	3.050	57	0.264	3.025	−0.025	. .	64	16	65	14
40	32 23 34.64	3	4.012	43	0.318	4.007	−0.005	. .	65	15	70	11
41	−61 50 2.10	3	− 3.846	22	−0.085	− 4.098	+0.252	+ 2	65	15	75	9
42	50 29 44.04	2	4.219	20	−0.211	4.122	−0.097	. .	72	10	76	8
43	80 42 29.16	3	4.118	22	+0.704	4.201	+0.083	+ 1	74	29	75	20
44	28 50 9.43	6	4.746	75	−0.332	4.740	−0,006	. .	69	51	68	25
45	27 47 29.78	3	5.006	46	−0.335	4.998	−0.008	. .	63	10	69	9
46	−26 14 3.71	6	− 5.554	64	−0.339	− 5.554	0.000	. .	70	23	72	17
47	36 55 4.34	3	6.333	62	−0.290	6.330	−0.003	. .	62	17	63	15
48	67 46 26.94	2	6.607	20	+0.005	6.601	−0.006	. .	67	14	73	10
49	29 6 28.83	4	6.870	65	−0.322	6.870	0.000	. .	63	20	64	15
50	43 5 56.35	3	7.178	38	−0.254	7.354	+0.176	+ 1	66	13	67	9
51	−28 42 56.71	3	− 8.469	27	−0.315	− 8.458	−0.011	. .	72	13	76	11
52	37 43 32.67	3	8.610	36	−0.278	8.608	−0.002	. .	69	11	69	8
53	88 34 24.81	5	9.482	59	+5.689	9.493	+0.011	+ 3	68	29	70	21
54	52 42 50.99	4	9.578	53	−0.191	9.586	+0.008	. .	69	14	70	13
55	39 43 17.25	4	10.029	59	−0.261	10.031	+0.002	. .	65	16	66	13
56	−24 0 57.35	5	−10.234	67	−0.315	−10.274	+0.040	. .	70	46	70	20
57	47 2 31.02	3	10.526	61	0.225	10.511	−0.015	. .	62	18	63	13
58	36 20 57.70	3	11.039	40	0.266	11.127	+0.088	. .	63	14	66	10
59	59 11 15.80	3	11.533	18	−0.142	11.535	+0.002	. .	61	20	65	14
60	77 9 43.22	4	11.745	30	+0.214	11.761	+0.016	+ 5	76	27	74	18

No.	Name	Mag.	R.A. 1900	Wt.	An. Var.	Wt./100	$\frac{d^2\alpha}{dt^2}$	Prec.	μ	$\Delta\mu$
			h m s		s		s	s	s	
61	δ Velorum	2.2	8 41 56.525	5	+ 1.6570	76	− 0.0021	+ 1.6556	+0.0014	
62	L 3639	5.5	54 31.542	3	1.4688	53	0.0054	1.4724	−0.0036	
63	α Volantis	4.2	9 0 52.051	3	0.9547	41	− 0.0224	0.9580	−0.0033	− 4
64	λ Velorum	2.5	4 19.048	5	+ 2.2044	87	+ 0.0045	+ 2.2072	−0.0028	
65	ζ Octantis	5.7	11 14.820	4	− 7.8511	35	− 1.6255	− 7.7614	−0.0897	− 47
66	β Carinae	2.0	12 6.284	5	+ 0.6769	86	− 0.0358	+ 0.7060	−0.0291	− 3
67	ι Carinae	2.5	14 24.746	7	1.6055	102	− 0.0023	1.6099	−0.0044	
68	θ Pyxidis	5.2	17 3.861	3	2.6519	50	+ 0.0035	2.6559	−0.0040	
69	κ Velorum	2.7	19 0.973	5	1.8553	68	0.0027	1.8582	−0.0029	
70	Ψ Velorum	3.7	26 45.612	4	2.3583	47	+ 0.0065	2.3766	−0.0183	− 1
71	L 3910	3.2	28 10.956	3	+ 1.8208	32	+ 0.0029	+ 1.8261	−0.0053	
72	ζ Chamael.	5.5	36 50.145	4	− 1.6050	34	− 0.2975	− 1.5950	−0.0100	− 2
73	υ Carinae	3.5	44 36.125	6	+ 1.5011	88	− 0.0046	+ 1.5040	−0.0029	
74	q Velorum	3.9	53 21.072	4	2.1013	45	+ 0.0094	2.1037	−0.0024	
75	ω Carinae	3.6	10 11 21 561	3	1.4295	42	− 0.0077	1.4370	−0.0075	− 2
76	L 4249	3.3	13 44.516	3	+ 1.9962	35	+ 0.0115	+ 2.0016	−0.0054	
77	L 4319	4.4	22 24.578	4	1.1977	43	− 0.0226	1.2060	−0.0083	− 3
78	α Antliae	4.4	22 34.479	4	2.7399	59	+ 0.0098	2.7472	−0.0073	
79	θ Carinae	2.9	39 23.240	4	2.1296	74	0.0202	2.1338	−0.0042	
80	η Carinae	Var.	41 10.817	5	2.3179	87	0.0220	2.3178	+0.0001	
81	μ Velorum	2.9	42 27.976	4	+ 2.5679	61	+ 0.0197	+ 2.5643	+0.0036	
82	δ Chamael.	4.9	44 50.801	4	0.6094	27	− 0.0978	0.6276	−0.0182	− 9
83	β Crateris	4.6	11 6 44.324	6	2.9452	135	+ 0.0099	2.9466	−0.0014	
84	π Centauri	4.3	16 26.739	3	2.7223	55	0.0308	2.7259	−0.0036	
85	ξ Hydrae	3.7	28 4.930	4	2.9432	57	0.0166	2.9599	−0.0167	
86	λ Centauri	3.4	31 9.951	3	+ 2.7434	48	+ 0.0450	+ 2.7510	−0.0076	
87	ε Chamael.	5.0	54 39.367	4	2.9137	34	0.1241	2.9302	−0.0165	− 7
88	δ Centauri	2.8	12 3 10.421	6	3.0895	91	0.0383	3.0949	−0.0054	
89	ρ Centauri	4.5	6 25.419	3	3.1148	39	0.0413	3.1203	−0.0055	
90	δ Crucis	3.4	9 49.976	5	3.1594	79	0.0533	3.1652	−0.0058	
91	β Chamael.	4.6	12 28.465	8	+ 3.4223	116	+ 0.1867	+ 3.4385	−0.0162	− 8
92	β Corvi	2.6	29 7.940	11	3.1432	134	0.0166	3.1441	−0.0009	
93	γ Centauri	2.4	35 59.951	6	3.2874	95	0.0417	3.3083	−0.0209	− 2
94	β Muscae	3.4	40 8.638	3	3.6300	34	0.1009	3.6368	−0.0068	
95	β Crucis	1.7	41 52.485	5	3.4716	97	0.0660	3.4793	−0.0077	
96	δ Muscae	3.7	55 23.164	5	+ 4.0520	55	+ 0.1426	+ 4.0025	+0.0495	+ 14
97	ι Centauri	3.0	13 14 58.394	3	3.3574	74	0.0303	3.3869	−0.0295	− 2
98	κ Octantis	5.7	24 42.357	4	8.8478	34	1.6090	8.9137	−0.0659	− 63
99	ε Centauri	2.6	33 32.938	5	3.7712	85	0.0591	3.7758	−0.0046	
100	ζ Centauri	2.7	49 17.916	4	3.7185	70	0.0472	3.7261	−0.0076	
101	β Centauri	1.2	56 45.782	7	+ 4.1926	126	+ 0.0848	+ 4.1970	−0.0044	
102	θ Centauri	2.2	14 0 47.712	3	3.5145	61	0.0319	3.5591	−0.0446	0
103	δ Octantis	4.7	10 51.751	8	9.0903	93	1.0434	9.1405	−0.0502	− 33
104	η Centauri	2.5	29 9.312	4	3.7909	69	0.0390	3.7948	−0.0039	
105	α Apodis	4.0	35 25.508	4	7.2333	45	0.4352	7.2396	−0.0063	
106	L 5823	6.8	39 0.093	6	+24.5734	88	+ 8.7641	+24.7503	−0.1769	−173
107	β Lupi	2.8	51 58.769	4	3.9093	57	0.0393	3.9149	−0.0056	
108	σ Librae	3.5	58 12.909	6	3.5015	103	0.0209	3.5079	−0.0064	
109	π Lupi	4.3	58 18.411	4	4.0635	54	0.0451	4.0670	−0.0035	
110	κ Lupi	4.5	15 4 58.737	4	4.1466	49	0.0475	4.1587	−0.0121	
111	ζ Lupi	3.6	5 5.908	4	+ 4.2838	51	+ 0.0548	+ 4.2968	−0.0130	
112	γ Tri. Aust.	3.1	9 34.186	4	5.5346	73	0.1399	5.5464	−0.0118	
113	ε Lupi	3.8	15 53.288	3	4.0538	36	0.0393	4.0579	−0.0041	
114	ρ Octantis	5.9	20 11.720	5	13.1358	40	1.4052	13.0437	+0.0921	+ 17
115	ε Tri. Aust.	4.6	27 33.872	3	5.4358	50.	0.1121	5.4331	+0.0027	+ 3
116	γ Lupi	3.2	28 28.458	4	+ 3.9813	72	+ 0.0331	+ 3.9844	−0.0031	
117	β Tri. Aust.	3.1	46 19.666	4	5.2437	71	0.0873	5.2742	−0.0305	+ 6
118	ρ Scorpii	4.5	50 42.487	3	3.6942	63	0.0198	3.6969	−0.0027	
119	π Scorpii	3.4	52 48.021	4	3.6202	78	0.0179	3.6226	−0.0024	
120	δ Scorpii	2.4	54 25.120	7	3.5400	148	0.0158	3.5416	−0.0016	

No.	Decl. 1900	Wt.	An. Var.	Wt. / 100	$\frac{d^2\delta}{dt^2}$	Prec.	μ'	$\Delta\mu'$	Ep.$_\alpha$	Wt. at Ep.	Ep.$_\delta$	Wt. at Ep.
	° ′ ″		″		″	″	″					
61	−54 20 32.05	4	−13.121	57	−0.178	−13.019	−0.102	. .	69	16	68	13
62	58 50 36.00	2	13.848	33	0.148	13.836	−0.012	. .	63	14	68	10
63	65 59 49.21	3	14.350	31	0.092	14.233	−0.117	0	69	11	71	10
64	43 1 43.78	4	14.443	67	−0.217	14.444	+0.001	. .	65	18	64	15
65	85 15 46.71	3	14.809	24	+0.784	14.857	+0.048	+ 9	74	32	75	23
66	−69 18 19.32	4	−14.823	62	−0.057	−14.908	+0.085	+ 3	63	30	65	20
67	58 51 20.41	4	15.050	56	0.147	15.042	−0.008	. .	66	27	68	17
68	25 32 22.92	3	15.195	31	0.245	15.195	0.000	. .	67	14	70	10
69	54 35 0.68	4	15.292	44	0.168	15.305	+0.013	. .	70	15	72	13
70	40 1 44.13	3	15.676	33	0.205	15.734	+0.058	+ 2	69	16	74	11
71	−56 35 35.55	3	−15.811	32	−0.157	−15.811	0.000	. .	72	12	72	10
72	80 29 30.99	3	16.245	22	+0.144	16.266	+0.021	+ 1	74	29	76	20
73	64 36 29.11	5	16.658	71	−0.116	16.653	−0.005	. .	66	22	66	18
74	54 5 30.71	3	17.082	41	0.153	17.067	−0.015	. .	72	15	71	12
75	69 32 28.93	3	17.848	29	0.087	17.841	−0.007	0	67	16	70	12
76	−60 49 57.56	3	−17.940	27	−0.122	−17.935	−0.005	. .	71	11	74	10
77	73 31 21.57	3	18.284	28	0.064	18.262	−0.022	0	71	17	74	14
78	30 33 31.41	3	18.276	44	0.156	18.267	−0.009	. .	67	16	70	12
79	63 52 14.36	3	18.832	56	0.099	18.824	−0.008	. .	60	15	64	12
80	59 9 31.54	4	18.881	61	0.106	18.878	−0.003	. .	63	26	63	17
81	−48 53 30.77	4	−18.986	36	−0.116	−18.916	−0.070	. .	68	14	74	11
82	80 0 45.81	4	18.975	29	0.020	18.983	+0.008	+ 1	74	28	74	22
83	22 16 47.78	5	19.623	67	0.090	19.513	−0.110	. .	66	14	72	10
84	53 56 35.38	2	19.718	35	0.067	19.691	−0.027	. .	63	11	67	9
85	31 18 15.77	3	19.917	43	0.051	19.858	−0.059	. .	69	15	70	11
86	−62 27 59.47	3	−19.918	36	−0.042	−19.894	−0.024	. .	67	11	71	10
87	77 39 54.21	3	20.067	33	−0.001	20.047	−0.020	0	74	13	74	11
88	50 9 55.86	4	20.074	60	+0.015	20.050	−0.024	. .	66	18	68	13
89	51 48 42.25	3	20.074	26	0.021	20.044	−0.030	. .	70	10	75	8
90	58 11 34.25	4	20.069	49	0.028	20.034	−0.035	. .	65	16	71	12
91	−78 45 25.08	6	−20.009	68	+0.036	−20.022	+0.013	0	66	39	70	26
92	22 50 37.63	5	19.950	71	0.067	19.890	−0.060	. .	68	51	68	25
93	48 24 38.45	4	19.827	58	0.083	19.805	−0.022	0	67	17	69	13
94	67 33 38.42	3	19.772	29	0.101	19.745	−0.027	. .	72	12	74	10
95	59 8 31.69	4	19.746	66	0.100	19.718	−0.028	. .	60	18	64	14
96	−71 0 34.40	4	−19.506	36	+0.152	−19.469	−0.037	+ 2	71	20	74	15
97	36 11 5.58	3	19.081	49	0.164	18.989	−0.092	− 1	60	13	66	11
98	85 16 24.83	3	18.724	25	0.470	18.698	−0.026	− 3	74	35	74	22
99	52 57 29.06	4	18.440	48	0.226	18.405	−0.035	. .	67	15	70	11
100	46 47 45.88	3	17.875	49	0.256	17.815	−0.060	. .	66	14	66	11
101	−59 53 26.24	5	−17.544	74	+0.305	−17.505	−0.039	. .	63	34	67	22
102	35 52 40.54	3	17.844	51	0.262	17.331	−0.513	− 3	62	12	65	11
103	83 12 34.98	5	16.878	63	0.720	16.871	−0.007	− 4	70	38	70	22
104	41 43 6.97	4	15.980	49	0.342	15.953	−0.027	. .	66	14	69	13
105	78 37 12.24	3	15.625	26	0.668	15.615	−0.010	. .	71	24	74	16
106	−87 44 30.56	5	−15.478	63	+2.282	−15.417	−0.061	−17	66	36	69	20
107	42 43 51.97	3	14.718	51	0.395	14.666	−0.052	. .	66	12	66	11
108	24 53 20.71	4	14.345	56	0.364	14.289	−0.056	. .	65	18	70	13
109	46 39 35.68	4	14.324	43	0.422	14.283	−0.041	. .	71	14	72	11
110	48 21 27.18	2	13.930	26	0.442	13.868	−0.062	. .	70	13	65	10
111	−51 43 7.28	3	−13.930	34	+0.456	−13.860	−0.070	. .	69	11	73	10
112	68 18 36.66	4	13.612	44	0.598	13.575	−0.037	. .	63	17	71	14
113	44 19 47.65	3	13.191	32	0.452	13.163	−0.028	. .	72	10	72	9
114	84 7 54.98	3	12.795	22	1.484	12.876	+0.081	+10	73	33	74	22
115	65 58 50.30	2	12.449	29	0.629	12.375	−0.074	0	64	14	70	9
116	−40 49 49.91	3	−12.349	51	+0.464	−12.313	−0.036	. .	63	14	66	12
117	63 7 18.92	3	11.441	40	0.639	11.043	−0.398	− 4	61	14	68	12
118	28 55 20.01	3	10.762	45	0.460	10.722	−0.040	. .	62	12	66	9
119	25 49 35.00	3	10.608	53	0.453	10.566	−0.042	. .	63	12	67	10
120	22 20 14.11	6	10.484	75	0.445	10.446	−0.038	. .	63	24	71	19

No.	Name	Mag.	R.A. 1900 (h m s)	Wt.	An. Var. (s)	Wt. / 100	$\frac{d^2a}{dt^2}$ (s)	Prec. (s)	μ (s)	$\Delta\mu$
121	L 6623	5.2	16 5 23.600	4	+ 8.8026	40	+ 0.3372	+ 8.8099	−0.0073	+ 3
122	L 6764	4.6	12 21.309	3	4.4699	45	0.0374	4.4888	−0.0189	0
123	σ Scorpii	3.4	15 6.517	5	3.6393	77	0.0154	3.6409	−0.0016	
124	γ Apodis	3.9	18 6.217	6	9.0555	67	0.3206	9.0973	−0.0418	+ 3
125	α Scorpii	1.4	23 16.453	12	3.6715	172	0.0149	3.6731	−0.0016	
126	τ Scorpii	3.2	29 39.354	4	+ 3.7278	89	+ 0.0150	+ 3.7292	−0.0014	
127	α Tri. Aust.	2.2	38 4.385	10	6.3116	134	0.0892	6.3087	+0.0029	+ 3
128	η Arae	3.8	41 8.847	4	5.1581	49	0.0414	5.1558	+0.0023	
129	ε Scorpii	2.3	43 41.083	4	3.8777	85	0.0161	3.9285	−0.0508	+ 1
130	ζ Arae	3.2	50 20.569	4	4.9487	48	0.0338	4.9518	−0.0031	
131	ε Arae	4.2	51 36.683	4	+ 4.7673	53	+ 0.0292	+ 4.7688	−0.0015	
132	η Scorpii	3.6	17 4 59.365	4	4.2888	61	0.0170	4.2881	+0.0007	+ 4
133	θ Ophiuchi	3.6	15 52.006	7	3.6801	97	0.0079	3.6818	−0.0017	
134	γ Arae	3.6	16 58.536	4	5.0390	67	0.0226	5.0407	−0.0017	
135	β Arae	2.8	16 59.142	4	4.9763	60	0.0218	4.9790	−0.0027	
136	Br 2198	4.5	20 15.698	7	+ 3.6591	84	+ 0.0072	+ 3.6613	−0.0022	
137	α Arae	2.9	24 6.620	4	4.6304	85	0.0147	4.6351	−0.0047	+ 2
138	Br 2209	5.2	25 18.786	5	3.6563	98	0.0064	3.6579	−0.0016	
139	λ Scorpii	2.0	26 49.010	4	4.0694	81	0.0088	4.0706	−0.0012	
140	θ Scorpii	2.1	30 7.932	3	4.3056	63	0.0096	4.3059	−0.0003	
141	κ Scorpii	2.6	35 34.160	4	+ 4.1468	68	+ 0.0073	+ 4.1482	−0.0014	
142	η Pavonis	3.8	35 54.992	3	5.8787	41	0.0212	5.8821	−0.0034	+ 2
143	ι Scorpii	3.3	40 35.380	4	4.1927	75	0.0062	4.1939	−0.0012	
144	γ Sagittarii	2.8	59 22.994	5	3.8516	55	0.0021	3.8579	−0.0063	+ 2
145	μ Sagittarii	4.3	18 7 46.962	9	3.5871	123	0.0007	3.5879	−0.0008	
146	δ Sagittarii	2.8	14 35.509	4	+ 3.8406	64	− 0.0008	+ 3.8389	+0.0017	
147	ε Sagittarii	2.2	17 32.094	3	3.9826	69	0.0018	3.9865	−0.0039	
148	λ Sagittarii	2.7	21 47.936	6	3.7019	95	0.0012	3.7068	−0.0049	+ 2
149	ζ Pavonis	4.2	31 21.094	5	7.0277	72	0.0429	7.0339	−0.0062	+ 11
150	q Sagittarii	3.7	39 24.525	6	3.7485	88	0.0043	3.7465	+0.0020	
151	λ Pavonis	4.3	42 57.129	3	+ 5.5710	45	− 0.0294	+ 5.5746	−0.0036	
152	σ Sagittarii	2.4	49 3.853	8	3.7209	158	0.0054	3.7218	−0.0009	
153	ζ Sagittarii	3.1	56 14.980	5	3.8192	89	0.0077	3.8221	−0.0029	
154	τ Sagittarii	3.6	19 0 41.798	3	3.7476	59	0.0072	3.7534	−0.0058	+ 2
155	Br 2478	4.7	30 37.342	5	3.6546	73	0.0104	3.6507	+0.0039	
156	Br 2549	4.7	56 30.584	6	+ 3.6944	102	− 0.0148	+ 3.6933	+0.0011	
157	α Pavonis	2.1	20 17 44.318	8	4.7737	120	0.0595	4.7741	−0.0004	+ 2
158	α Indi	3.1	30 32.063	4	4.2363	73	0.0398	4.2337	+0.0026	
159	β Pavonis	3.3	35 57.052	5	5.4612	78	0.1163	5.4696	−0.0084	
160	Ψ Capricorni	4.3	40 10.530	4	3.5583	73	0.0167	3.5637	−0.0054	
161	β Indi	3.7	46 59.743	3	+ 4.7209	48	− 0.0733	+ 4.7216	−0.0007	
162	γ Pavonis	4.5	21 18 10.623	4	5.0155	65	0.1240	5.0045	+0.0110	− 22
163	ζ Capricorni	3.7	20 57.530	5	3.4321	98	0.0166	3.4329	−0.0008	
164	γ Gruis	3.0	47 52.484	3	3.6456	50	0.0309	3.6387	+0.0069	
165	α Gruis	1.9	22 1 55.945	7	3.8010	104	0.0455	3.7901	+0.0109	
166	α Tucanae	2.8	11 39.151	4	+ 4.1481	70	− 0.0844	+ 4.1600	−0.0119	+ 3
167	ν Octantis	6.4	12 35.050	9	12.8348	103	3.2001	12.8781	−0.0433	+ 11
168	L 9138	4.2	23 17.673	3	3.6032	36	0.0386	3.6015	+0.0017	
169	β Octantis	4.4	35 50.973	7	6.4182	93	0.6268	6.4470	−0.0288	+ 19
170	β Gruis	2.2	36 41.830	3	3.6009	61	0.0434	3.5897	+0.0112	
171	ε Gruis	3.5	42 30.911	4	+ 3.6459	60	− 0.0514	+ 3.6371	+0.0088	
172	α Pis. Aust.	1.4	52 7.534	10	3.3233	141	0.0210	3.2994	+0.0239	
173	ι Gruis	3.9	23 4 41.981	3	3.4127	43	0.0376	3.4010	+0.0117	
174	τ Octantis	6.0	13 9.775	9	10.9882	108	5.2409	10.9656	+0.0226	− 72
175	β Sculptoris	4.8	27 36.602	3	3.2280	47	0.0258	3.2218	+0.0062	
176	ι Phoenicis	4.5	29 41.800	3	+ 3.2381	34	− 0.0306	+ 3.2380	+0.0001	
177	δ Sculptoris	4.6	43 43.022	6	3.1304	68	0.0160	3.1246	+0.0058	
178	L 9607	5.5	46 14.539	7	3.6601	92	0.3153	3.6882	−0.0281	+ 20
179	ε Tucanae	4.3	54 43.269	3	3.1485	42	0.0690	3.1423	+0.0062	

No.	Decl. 1900	Wt.	An. Var.	Wt. 100	$\frac{d^2\delta}{dt^2}$	Prec.	μ'	$\Delta\mu'$	Ep.$_\alpha$	Wt. at Ep.	Ep.$_\delta$	Wt. at Ep.
	° ′ ″		″		″	″	″					
121	−78 26 37.38	2	− 9.650	16	+1.130	− 9.614	−0.036	− 1	72	29	76	19
122	49 54 36.87	3	9.137	35	0.583	9.076	−0.061	− 2	69	13	72	11
123	25 21 10.51	4	8.891	48	0.480	8.860	−0.031	. .	69	16	70	13
124	78 40 21.03	3	8.703	31	1.190	8.624	−0.079	− 5	70	22	73	17
125	26 12 36.78	6	8.243	75	0.492	8.214	−0.029	. .	67	55	68	26
126	−28 0 31.60	4	− 7.748	57	+0.506	− 7.701	−0.047	. .	60	18	68	14
127	68 50 38.67	5	7.064	62	0.866	7.016	−0.048	0	67	45	70	25
128	58 51 46.52	3	6.822	36	0.711	6.764	−0.058	. .	69	12	73	11
129	34 6 42.73	3	6.813	56	0.530	6.554	−0.259	− 7	60	15	65	12
130	55 49 56.16	3	6.051	31	0.688	6.001	−0.050	. .	70	16	72	10
131	−53 0 24.79	3	− 5.920	37	+0.667	− 5.895	−0.025	. .	68	13	71	10
132	43 6 26.89	3	5.073	52	0.610	4.767	−0.306	0	67	16	67	13
133	24 53 59.57	6	3.876	59	0.528	3.838	−0.038	. .	66	30	73	19
134	56 17 0.66	3	3.768	46	0.723	3.742	−0.026	. .	64	13	68	11
135	55 26 7.54	3	3.788	40	0.711	3.741	−0.047	. .	65	14	72	11
136	−24 5 0.80	5	− 3.592	48	+0.527	− 3.459	−0.133	. .	73	17	75	14
137	49 47 49.18	3	3.233	50	0.668	3.128	−0.105	− 1	63	16	67	13
138	23 53 7.47	3	3.056	42	0.528	3.023	−0.033	. .	65	11	73	8
139	37 1 51.69	4	2.934	54	0.588	2.893	−0.041	. .	64	15	68	13
140	42 56 3.51	3	2.630	44	0.624	2.606	−0.024	. .	63	12	70	10
141	−38 58 42.21	3	− 2.158	51	+0.602	− 2.134	−0.024	. .	64	13	66	11
142	64 40 33.16	3	2.171	32	0.853	2.103	−0.068	0	70	12	75	10
143	40 5 17.54	3	1.695	44	0.610	1.696	+0.001	. .	64	14	69	11
144	30 25 30.70	4	− 0.246	44	0.561	− 0.054	−0.192	− 1	71	19	72	16
145	21 5 6.06	5	+ 0.685	58	0.522	+ 0.681	+0.004	. .	67	45	69	23
146	−29 52 14.92	2	+ 1.225	29	+0.558	+ 1.276	−0.051	. .	66	15	65	12
147	34 25 54.78	3	1.404	52	0.577	1.532	−0.128	. .	58	16	63	12
148	25 28 37.39	5	1.710	68	0.536	1.904	−0.194	− 1	66	22	69	16
149	71 30 49.45	3	2.565	22	1.013	2.735	−0.170	− 1	69	23	76	17
150	27 5 37.61	4	3.410	53	0.537	3.431	−0.021	. .	66	21	67	15
151	−62 18 7.33	2	+ 3.709	31	+0.798	+ 3.736	−0.027	. .	67	11	70	9
152	26 25 15.67	6	4.192	81	0.528	4.260	−0.068	. .	62	34	69	22
153	30 1 23.16	4	4.866	49	0.538	4.872	−0.006	. .	64	19	70	15
154	27 49 0.01	2	4.983	43	0.524	5.249	−0.266	− 1	62	11	64	10
155	25 6 15.76	5	7.695	63	0.489	7.724	−0.029	. .	67	27	69	18
156	−27 59 16.89	5	+ 9.759	52	+0.467	+ 9.760	−0.001	. .	66	24	72	17
157	57 3 19.90	5	11.240	63	0.570	11.339	−0.099	0	67	34	68	20
158	47 38 25.07	3	12.289	50	0.484	12.244	+0.045	. .	65	15	67	13
159	66 33 45.28	3	12.607	42	0.613	12.616	−0.009	. .	67	20	70	14
160	25 37 49.28	3	12.739	52	0.391	12.901	−0.162	. .	63	12	67	10
161	−58 49 53.11	3	+13.321	24	+0.508	+13.352	−0.031	. .	68	12	75	8
162	65 49 7.61	3	16.036	51	0.169	15.258	+0.778	+ 1	64	16	66	13
163	22 50 40.22	5	15.432	60	0.313	15.415	+0.017	. .	66	15	73	12
164	37 50 6.65	3	16.794	54	0.283	16.811	−0.017	. .	66	13	64	13
165	47 26 43.53	5	17.264	62	0.266	17.449	−0.185	. .	67	31	68	19
166	−60 45 29.65	3	+17.790	56	+0.267	+17.853	−0.063	− 1	62	15	65	13
167	86 28 33.73	6	17.955	68	0.835	17.890	+0.065	− 3	69	42	70	24
168	44 0 23.83	3	18.269	33	0.207	18.293	−0.024	. .	72	11	72	10
169	81 54 19.91	6	18.713	67	0.326	18.716	−0.003	− 2	68	37	70	24
170	47 24 27.34	3	18.712	38	0.179	18.742	−0.030	. .	62	14	68	10
171	−51 50 31.06	3	+18.839	39	+0.168	+18.917	−0.078	. .	67	15	71	13
172	30 9 8.27	6	19.005	75	0.134	19.179	−0.174	. .	67	53	68	25
173	45 47 18.64	3	19.421	25	0.111	19.472	−0.051	. .	69	13	73	11
174	88 1 52.92	6	19.642	69	0.317	19.635	+0.007	+ 1	70	45	69	25
175	38 22 17.05	2	19.854	25	0.058	19.852	+0.002	. .	66	12	72	9
176	−43 10 5.00	3	+19.865	32	+0.054	+19.877	−0.012	. .	71	12	70	10
177	28 40 59.96	4	19.893	40	0.024	20.002	−0.109	. .	71	32	71	17
178	82 34 28.66	5	19.997	59	0.023	20.016	−0.019	0	68	34	70	22
179	66 8 0.29	3	20.016	25	0.002	20.047	−0.031	. .	69	11	71	9

ON A NEW VARIABLE OF THE *ALGOL*-TYPE,

(1855) $18^h\ 23^m\ 56^s$, $+12°\ 30'.9$; (1900) $18^h\ 26^m\ 1^s$, $+12°\ 32'.6$.

By EDWIN F. SAWYER.

I wish to announce that I have discovered that DM. +12°3557 is a variable of the *Algol*-type, with a period of about $21^h\ 21^m$, the fluctuations in brightness being about half a magnitude, or from $7^M.0$ to $7^M.5$. The decrease to minimum apparently occupies two hours and a half, and the increase a like interval of time. The star is No. 2510 of the Potsdam Photometric Catalogue, and was observed once each by Kempf and Müller, 1888 Sept. 24 as $7^M.74$, and 1890 Oct. 29 as $7^M.57$. Both observations being evidently made near minimum, and agreeing very closely, no further observations were deemed necessary, and the mean $7^M.66$ was entered in their catalogue as the magnitude of the star; the DM. magnitude being $7^M.0$. In the course of my revision of this work which was begun in 1895, and is now nearly completed, I had occasion to observe the star on 1895 Sept. 15 and 1896 Oct. 26, my determinations of magnitude being $7^M.26$ and $7^M.28$, respectively, both being taken when the star was near its normal brightness. Thus while the mean results determined at Potsdam and Brighton agreed very closely amongst themselves, the mean results between the two observations showed a discordance of nearly half a magnitude. Since, however, discordances of this amount are not infrequent between the two catalogues, and especially in cases where the stars are highly colored, particular attention was not attracted to this difference, although the star was marked for some future examination when the time allowed, in accordance with my custom in cases of this kind. In going over this region during the present year this star was selected amongst some others for additional observations, and on Sept. 9 in comparison with other stars in its vicinity it was found to be $7^M.45$. Comparing this value with my former determinations the next day, the discordance was at once noted, and it was marked for another observation. On the following evening, Sept. 10, the sky was overcast, but on the 11th the star was observed and found to be $7^M.02$. My suspicions of the star's constancy was now aroused, and close watch was kept of it; but the brightness remained apparently constant until Sept. 16, when an early observation at $7^h\ 40^m$ found the star constant, while at a later observation at $9^h\ 15^m$ (when, however, the star was getting low and difficult to observe) it was noted as faint, or $7^M.35$. Although the star was now very closely watched no further evidence of variability rewarded my vigilance until Oct. 3, when a partial decrease and increase was observed, and a fairly marked minimum was possible of determination. The period was then quite uncertain, but was apparently about a week or some aliquot part. It was not until Oct. 12 that a solution of the difficulty was arrived at, and the approximate elements given below, and the nature of the variation, determined. The comparison-stars used and their magnitudes, as determined at Potsdam and Brighton, are as follows, the positions being for 1900.0.

		α	δ	Potsdam	Sawyer
		h m s	° ′	M	M
a =	DM. +13°3658 =	18 24 52	+ 13 47.5	7.12	7.27
b =	DM. +13°3677 =	18 27 34	+ 13 39.5	7.36	7.47
c =	DM. +12°3598 =	18 32 0	+ 12 54.8	7.48	7.58

In the following table all my observations to date, with deduced magnitudes, using the Potsdam magnitudes for the comparison-stars, are given:

	Boston M.T.			
		h	m	M
1895 Sept.	15	8	30?	7.09
1896 Oct.	26	6	30?	7.09
1898 Sept.	9	9	0?	7.45
	11	9	0	7.02
	12	7	20	7.02
	13	7	15	7.02
	14	7	40	7.02:
	15	10	20	7.02:
	16	7	40	7.02:
		9	15	7 35:
	18	7	0	7.02:
	20	7	0	7.02
		9	15	7.02
	21	6	50	7.02
		9	20	7.02
	23	6	50	7.02:
		9	30	7.02:
	27	7	0	7.02:
		9	10	7.02:
	29	7	0	7.02:
		9	30	7.02:
	30	7	0	7.02:
		9	0	7.02:
Oct.	3	6	35	7.30
		7	0	7.37
		7	20	7.43
		7	40	7.50
		8	10	7.53
		8	45	7.48
		9	35	7.32
	5	9	15	7.12
	6	8	0	7.02
		9	50	7.02
	7	7	40	7.02
	8	6	30	7.02
	9	6	30	7.02

	Boston M.T.			
		h	m	M
1898 Oct.	10	6	15	7.02:
		6	50	7.02:
		8	0	7.02:
		8	30	7.02:
		9	45	7.40:
		10	0	7.50:
	11	6	15	7.02
		7	0	7.12
		7	20	7.37:
		7	40	7.42:
	12	6	15	7.29:
		6	30	7.30:
		7	5	7.24:
		7	12	7.20:
		7	35	7.17:
		8	15	7.09:
		8	45	7.09:
	13	6	30	7.07
		7	30	7.07
		9	10	7.07
	15	6	30	7.02
	16	6	20	7.02
		7	0	7.02
		8	10	7.02
		8	45	7.02
		9	0	7.02
	17	6	30	7.02
		7	30	7.02
		9	10	7.02
	20	6	0	7.40
		6	30	7.30
		7	0	7.25
		8	15	7.12
	23	6	30	7.02
	27	6	15	7.30:*
		7	30	7.50:

* Strong moonlight.

This table shows that the star was near minimum at the observations of Sept. 9 and 16, Oct. 3, 10, 11, 12, 20 and 27. By means of three observations combined with those taken at Potsdam the epoch and period were approximately determined as 1898 Oct. 3, $13^h\ 1^m$ Gr. M.T. $+0^d\ 21^h\ 21^m$ E. A few well observed minima will soon allow of a better determination of the elements.

Brighton, 1898 *October* 29.

OBSERVATIONS OF (247) *EUKRATE*, FROM PHOTOGRAPHIC MEASUREMENTS,

[Communicated by F. P. LEAVENWORTH.]

1898 Northfield M.T.	Planet's Mean α	Planet's Mean δ	log pΔ α	log pΔ δ
	h m s	° ′ ″		
Jan. 13 11 15 54	7 41 11.81	+62 9 18.1	n9.293	n0.409
17 10 37 24	7 33 40.75	+61 44 54.1	n9.400	n0.382
1898 Minneapolis M.T.				
Jan. 21 10 18 25	7 26 40.29	+61 12 36.9	n9.358	n0.360
28 11 5 38	7 16 8.41	+59 58 45.0	8.922	n0.355
31 11 8 36	7 12 29.42	+59 21 42.5	9.177	n0.339

The first two measures were made from photographs taken at the Goodsell Observatory by Dr. H. C. WILSON. The other three are from photographs taken at the Observatory of the University of Minnesota, longitude $6^h\ 12^m\ 56^s.8$, latitude 44° 58′ 40″. The first two were reduced by myself, the Minneapolis ones by R. Y. FERNER, B. L. NEWKIRK, and P. E. DAVIS, students of the University.

The places are for the beginning of the year. Each depends on from six to nine stars whose positions are from Helsingfors-Gotha A.G. Zones.

The observers would like to hear from computers using the measures, of the degree of accuracy obtained by them, from this method.

Minneapolis, Minn., 1898 *Sept.* 17.

RESEMBLANCE OF THE ORBITS OF COMETS *i* 1898 AND 1881 IV,

BY C. D. PERRINE.

There is a striking similarity between the orbits of these two comets, as will be seen from a comparison of their elements.

Comet	ω	Ω	i	q
	° ′	° ′	° ′	
i 1898	122 8	97 17	140 14	0.6335
1881 IV	123 22	96 10	140 19	0.7564

The elements of SCHAEBERLE's comet are the definitive elements by STECHERT, brought up to 1898.0; those of BROOKS's comet are by HUSSEY from two-day intervals.

SCHAEBERLE's comet was observed for three months, and the resulting orbit shows that it is not possible for BROOKS's comet to be a return of SCHAEBERLE's. The resemblance is so close, however, as to indicate a strong family connection, and the necessity for a good series of observations.

Lick Observatory, University of California, 1898 *October* 26.

OBSERVATIONS OF COMET *i* 1898 (BROOKS),

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

BY WILLIAM J. HUSSEY.

1898 Mt.Hamilton M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Oct. 21 7 8 4	1	10 , 8	—2 3.27	—7 21.9	15 3 35.63	+57 55 18.4	9.944	0.489
23 6 57 45	2	8 , 8	+0 32.58	—6 39.6	15 42 57.09	+52 49 22.2	9.883	0.373
7 10 45	2	8 , 4	+0 42.36	—8 8.2	15 43 6.87	+52 47 53.4	9.885	0.407
24 7 21 9	4	8 , 8	+0 12.82	—7 30.1	15 59 29.04	+49 57 21.0	9.858	0.455
8 19 47	6	8 , 8	+2 13.86	+2 11.0	16 0 6.08	+49 50 19.4	9.855	0.420
25 6 41 36	7	16 , 10	—0 35.16	+4 32.8	16 13 22.51	+47 7 2.0	9.814	0.298
26 7 39 18	8	10 , 10	—0 4.87	+3 12.7	16 26 24.42	+44 1 36.8	9.810	0.498

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 5 39.35	—0.45	+58 2 49.3	—9.0	Krueger, Helsingfors-Gotha A.G. Catal. 8244
2	15 42 24.65	—0.14	+52 56 6.3	—4.5	10ᵐ. Connected with *3
3	15 42 34.02	—0.14	+52 59 39.5	—4.5	Rogers, Cambridge, Mass., A.G. Catal. 4830
4	15 59 16.01	+0.21	+50 4 54.2	—3.1	10ᵐ. Connected with *5.
5	15 57 7.65	+0.20	+50 7 28.8	—2.8	Rogers, Cambridge, Mass., A.G. Catal. 4885
6	15 57 51.99	+0.23	+49 48 11.1	—2.7	Deichmüller, Bonn A.G. Catal. 10275
7	16 13 57.23	+0.44	+47 2 30.0	—0.8	" " " " 10449
8	16 26 28.63	+0.66	+43 58 23.5	+0.6	" " " " 10564

OBSERVATIONS OF TWO ASTEROIDS, PROBABLY NEW,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

BY E. F. CODDINGTON.

1898 Mt. Hamilton M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's apparent α	Planet's apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
Oct. 14 13 22 48	1	8 , 8	—0 8.38	+1 30.5	1 4 43.63	+8 33 54.3	9.352	0.636
15 10 4 16	2	8 , 9	+0 3.95	—4 3.3	1 4 9.54	+8 24 59.0	n9.212	0.632
16 9 13 22	4	6 , 8	+2 3.43	—4 53.2	1 3 30.69	+8 14 53.3	n9.396	0.643
18 11 18 4	5	8 , 8	+0 19.14	+3 32.8	1 2 8.91	+7 53 28.1	8.164	0.633
19 11 44 24	6	8 , 8	+0 5.54	—6 24.8	1 1 29.48	+7 43 0.9	8.845	0.636
Oct. 14 15 16 49	7	10 , 10	+0 17.01	+2 42.5	1 0 52.61	+9 40 24.4	9.604	0.663
15 11 22 35	8	8 , 8	—0 4.35	—4 13.6	1 0 2.41	+9 35 6.6	6.327	0.609
16 11 23 56	10	8 , 8	+0 20.92	—5 6.2	0 59 2.53	+9 28 51.6	8.237	0.610
19 11 0 22	11	8 , 8	—0 21.60	—2 12.0	0 56 6.60	+9 10 1.5	n7.148	0.615
20 10 44 36	12	8 , 8	—0 12.28	+0 45.0	0 55 9.79	+9 3 53.9	n8.379	0.617
11 25 38	14	10 , 8	—1 25.37	—0 9.0	0 55 7.85	+9 3 42.5	8.784	0.617

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 4 47.33	+4.68	+8 31 54.1	+29.7	DM. +8°181. Connected with *3
2	1 4 0.91	+4.68	+8 28 32.6	+29.7	DM. +8°179. Connected with *3
3	1 6 23.14	+4.69	+8 32 55.2	+29.6	Bonn Observations 184
4	1 1 22.58	+4.68	+8 19 16.7	+29.8	½ (Schjellerup 336 + Paris 1431)
5	1 1 45.08	+4.69	+7 49 25.5	+29.8	10ᴹ. Connected with *6
6	1 1 19.24	+4.69	+7 48 55.8	+29.8	½ (Yarnall 584 + Glasgow 270)
7	1 0 30.92	+4.68	+9 37 12.1	+29.8	11ᴹ. Connected with *9
8	1 0 2.08	+4.68	+9 38 50.4	+29.8	11ᴹ. Connected with *9
9	0 58 13.75	+4.68	+9 33 43.5	+29.9	Yarnall 556
10	0 58 36.93	+4.68	+9 33 27.9	+29.9	11ᴹ. Connected with *9
11	0 56 23.50	+4.70	+9 11 43.4	+30.1	½ (Yarnall 533 + Glasgow 254)
12	0 55 17.33	+4.70	+9 2 38.7	+30.2	12ᴹ. Connected with *13.
13	0 55 22.60	+4.70	+8 56 13.9	+30.2	½ (Yarnall 526 + Paris 1307)
14	0 56 28.51	+4.71	+9 3 21.3	+30.2	Yarnall 534

The magnitudes of the planets are respectively 11ᴹ.5 and 12ᴹ.5. The observations of Oct. 20 were made with the 36-inch refractor. These planets were discovered by means of their trails on a plate which I obtained with the Crocker Photographic Telescope, Oct. 13, 1898. I have not succeeded in identifying them with any of those already known.

CIRCULAR ELEMENTS FOR THE FOREGOING ASTEROIDS,

BY WILLIAM J. HUSSEY.

On a negative which he obtained with the Crocker telescope Oct. 13, Mr. CODDINGTON has found the trails of three minor planets, of which two appear to be new. From his observations of Oct. 14 and 18, I have computed the following circular elements of the brighter of these two, *i.e.*, the first one for which his observations are given in the foregoing article.

Epoch = 1898 Oct. 14.5 Gr. M.T.

$M = 177° 3′ 5″$
☊ $= 202\ 5\ 16$
$i = 21\ 28\ 44$
$\log a = 0.49539$
$\mu = 641''.1$

EPHEMERIS.

Gr. M.T.	α	δ	log Δ
	h m s	° ′	
Nov. 1.5	0 54 7	+5 39.0	
5.5	52 15	5 3.6	
9.5	0 50 38	+4 30.5	0.3541

From Mr. CODDINGTON's observations of Oct. 14 and 20, I have computed the following circular elements of the second, or fainter of these objects.

Epoch = Oct. 14.5 Gr. M.T.

$M = 81° 59′ 34″$
☊ $= 297\ 37\ 32$
$i = 1\ 35\ 12$
$\log a = 0.33185$
$\mu = 1127''.8$

EPHEMERIS.

Gr. M.T.	α	δ	log Δ
	h m s	° ′	
Nov. 1.5	0 45 31	+7 56.6	0.0835
5.5	43 2	7 37.5	0.0919
9.5	41 2	7 20.9	0.1013
13.5	39 33	7 7.5	0.1114
17.5	0 38 36	+6 57.1	0.1222

ELEMENTS OF THE PLANET *DQ*,

By HENRY NORRIS RUSSELL.

The following normal places of the planet *DQ* have been obtained by comparison of observations printed in the *Astronomische Nachrichten* and the *Astronomical Journal* with Berberich's ephemeris in *A.N.* 3517, with application of all necessary corrections for parallax, aberration, etc.

Berlin Mean Time	α (1898.0)	δ (1898.0)	No. Obs.
	° ′ ″	° ′ ″	
1898 Aug. 18.5000	319 45 51.9	−6 20 50.0	34
26.5000	316 14 26.3	−6 17 57.6	16
Sept. 9.5000	311 25 18.9	−6 20 17.2	26

From these three places the following elements have been computed. The heliocentric arc described by the planet is about 8°.

Princeton University, 1898 *Nov.* 7.

Epoch 1898 Aug. 31.5 Berlin M.T.

$$M = 224^\circ\ 33'\ 12''.3$$
$$\left.\begin{aligned}\omega &= 175\ 47\ 50.1\\ \Omega &= 303\ 20\ 20.3\\ i &= 10\ 45\ 1.8\end{aligned}\right\}\ 1898.0$$
$$\varphi = 12\ 55\ 13.6$$
$$\mu = 2003''.86$$
$$\log a = 0.1654245$$

Period 646.75 days

Constants for the Equator of 1898.0.

$$x = [9.9946616]\,r\,\sin(v+209^\circ\ 36'\ 13''.2)$$
$$y = [9.9417527]\,r\,\sin(v+114\ 35\ 0.6)$$
$$z = [9.7071184]\,r\,\sin(v+135\ 3\ 26.5)$$

OBSERVATIONS OF PLANET *DQ*,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 26-INCH EQUATORIAL,

By Prof. STIMSON J. BROWN, U.S.N.

[Communicated by Prof. Wm. Harkness, U.S.N., Astronomical Director.]

1898 Washington M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's Apparent α	Planet's Apparent δ	log pΔ for α	log pΔ for δ
h m			s	′ ″	h m s	° ′ ″		
Sept. 11 9 29.8	1	4 , 5	+14.96	−2 10.4	20 43 37.69	−6 20 35.9	8.3383	0.7962
12 8 41.05	2	4 , 5	− 4.61	+2 15.7	20 42 45.45	−6 20 18.1	n8.8313	0.7956
13 9 15.60	3	4 , 5	+33.25	−0 8.1	20 41 53.10	−6 21 2.0	8.0831	0.7981

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 43 18.41	+4.32	−6 18 43.6	+18.1	Munich I, 10842
2	20 42 45.72	+4.34	−6 23 51.9	+18.1	Munich I, 10832
3	20 41 15.56	+4.29	−6 21 11.8	+17.9	Weisse's Bessel 20h997

USEFULNESS OF THE PLANET *DQ* FOR DETERMINING THE SOLAR PARALLAX,

By SIMON NEWCOMB.

The elements of planet *DQ* computed by Professor Hussey, and found in No. 447 of this *Journal* are, it may be supposed, accurate enough to admit of a forecast of the future oppositions of the planet. The next opposition, 1900 November and December, will be unusually favorable for measurements of the parallax. The longitude of the perihelion being 120°, the best oppositions for this purpose will be those occurring nearest to the date January 20. Accepting Hussey's period I find that no opposition as good as the next will occur until 1924, when we shall have an opposition about equally favorable. In January, 1931, an opposition very near perihelion is likely.

Owing to the unusual character of the orbit of *DQ*, its geocentric motion will sometimes present singular features. At perihelion its linear velocity in its orbit is very near that of the earth. Hence, should an opposition then occur, the geocentric longitude will be nearly stationary for several days. This makes perihelion oppositions rare. Were the oppositions equally distributed through the year, one out of six would occur within a month of January 20. Actually I do not think that one out of twelve will so occur.

I have computed the following rough ephemeris for the next period of nearest approach with three-place logarithms. The logarithms are insufficient to give the last figure with precision, but the uncertainty of the elements is much greater.

	α	δ	Δ
	h m	°	
1900 Nov. 15	1 56	+51.7	0.358
20	1 45	54.0	.346
25	1 38	52.7	.336
30	1 32	51.5	.328
Dec. 5	1 30	49.7	.322
10	1 32	48.2	.314
15	1 34	46.0	.309
20	1 42	43.9	.310
25	1 48	+41.3	0.308

The declination of the planet affords a hint why it has so long escaped detection, and suggests a careful study of the best methods of measuring its parallax in 1900. Little can be done in the southern hemisphere until after the date of nearest approach, because even so far north as the Cape the planet will not culminate above the horizon before opposition. But in every part of the northern hemisphere its position among the stars can be fixed from hour to hour both by the photographic telescope and the heliometer. The combination of observations in the Eastern and Western hemispheres will then, it may be hoped, suffice for the best determination of the solar parallax yet made by direct measurement.

ELEMENTS AND EPHEMERIS OF THE SMALL PLANET *DQ*,

By S. C. CHANDLER.

The following orbit was computed from observations covering the interval Aug. 14 to Nov. 16.

Epoch 1898 Aug. 31.5 Gr. M.T.

$$M = 219^\circ\ 59'\ 23''.8$$

$$\left.\begin{aligned}\omega &= 178\ 40\ \ 7.3\\ \Omega &= 303\ 36\ \ 1.1\\ i &= \ 10\ 51\ 31.2\end{aligned}\right\}1898.0 \qquad \begin{aligned}\mu &= 2023''.656\\ \log a &= 0.162580\\ &\text{Period } 640.42 \text{ days.}\end{aligned}$$

$$\varphi = 12\ 51\ \ 1.6$$

Ephemeris for Greenwich Midnight.

1898	α	δ	log Δ	Mag.
	h m s	° ′		
Nov. 20.5	21 27 9	−3 7.3		
22.5	30 36	2 52.9		
24.5	34 6	2 38.0	0.1190	12.4
26.5	37 41	2 22.5		
28.5	41 22	2 6.6		
30.5	45 6	1 50.0		
Dec. 2.5	21 48 54	−1 32.9	0.1351	12.5

ELEMENTS AND EPHEMERIS OF COMET *i* 1898,

By WILLIAM J. HUSSEY.

From my observations of Oct. 21, 23 and 25, I have computed the following elements and ephemeris of this comet. The brightness at the time of the first of these observations is taken as unity.

Elements.

$$T = \text{Nov. } 23.13518 \text{ Gr. M.T.}$$

$$\left.\begin{aligned}\omega &= 123^\circ\ 22'\ 21''.1\\ \Omega &= \ 96\ 10\ \ 6.2\\ i &= 140\ 18\ 58.1\end{aligned}\right\}\text{Ecliptic and Mean Equinox 1898.0}$$

$$\log q = 9.878746$$

$$\text{O}-\text{C}:\quad \Delta\lambda'\cos\beta' = +0''.6\ ,\quad \Delta\beta' = -1''.6.$$

Constants for the Equator of 1898.0.

$$x = r[9.887974]\sin(v+115^\circ\ 22'\ 42''.4)$$
$$y = r[9.968174]\sin(v+224\ 25\ 55.5)$$
$$z = r[9.865944]\sin(v+155\ 58\ 21.5)$$

Lick Observatory, Mt. Hamilton, Cal., 1898 *Nov.* 8.

The following ephemeris is a continuation of that given in *A.J.* No. 447, the elements being the same. I have made a direct computation of the comet's place corresponding to the time of my observation of Nov. 5th, and obtain the following residuals: O−C, $\Delta\alpha = +1^s.04$, $\Delta\delta = -0''.1$. These are so small that a new determination of the elements at the present time seems unnecessary. The brightness on Oct. 21 is taken as unity.

Gr. M.T.	True α	True δ	log Δ	Br.
1898	h m s	° ′ ″		
Nov. 22.5	18 9 20.4	− 4 42 25	0.1057	0.40
24.5	18 11 4.2	6 24 44	0.1245	
26.5	18 12 32.9	7 59 47	0.1420	0.33
28.5	18 13 48.9	9 28 31	0.1585	
30.5	18 14 54.3	10 51 42	0.1738	0.28
Dec. 2.5	18 15 50.9	12 10 0	0.1881	
4.5	18 16 40.2	13 23 59	0.2014	0.23
6.5	18 17 23.6	14 34 8	0.2138	
8.5	18 18 2.1	−15 41 52	0.2253	0.20

CONTENTS.

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THE VARIATION OF LATITUDE AT NEW YORK, AND A DETERMINATION OF THE CONSTANT OF ABERRATION FROM OBSERVATIONS AT THE OBSERVATORY OF COLUMBIA UNIVERSITY,

By JOHN K. REES, HAROLD JACOBY AND HERMAN S. DAVIS.

Second Paper.

The present paper contains an account of observations made in continuation of those described in No. 401 of this *Journal*. The instrument employed has been the same zenith telescope by Wannschaff; the observers have been Professor Rees and Dr. Davis. Under the general supervision of Professor Jacoby the computations have been made by Miss F. E. Harpham, assisted by Miss Eudora Magill. To the liberality of Miss Catharine W. Bruce the Observatory is indebted for funds which have secured the efficient assistance of these computers. The observations so far made fall naturally into three series, as follows:

Series A, May 1893 to July 1894,	818	pairs	by	Rees
	302	"	"	Jacoby
	654	"	"	Davis
B, July 1894 to Jan. 1896,	771	"	"	Rees
	310	"	"	Davis
C, Jan. 1896 to Jan. 1898,	1065	"	"	Rees
	774	"	"	Davis

Series A consists of the observations already treated in *A.J.* 401. At the end of series B it became necessary to move the latitude observatory on account of building operations at the new site of the University. The latitude difference of the two positions was very carefully measured by Rees and Jacoby, and found to be 7″.337, with a possible error of only one or two units of the last decimal place. The observations at the new station were reduced to the old by means of this constant, and the whole three series may therefore be treated as if they had been made in the same place.

Careful determinations of the errors of the micrometer screw were made during series B and C, and a check was thus obtained upon the constancy of these quantities. The declination reductions for the nights when it was impossible to observe complete groups were determined for each series separately from the complete nights within that series. The three series may indeed be considered practically independent of each other so far as the reductions are concerned.

The following table exhibits the mean values for the observed differences of the latitudes from the successive groups, together with the effect on them of any error in Struve's aberration constant. The quantity x is $\frac{1}{20.4451}$ part of the correction required by the constant 20″.4451.

Table of Mean Observed Differences of Latitude.

Series	Group	Diff. of Latitudes and Ab. Effect	Weight
A	I–II	$-0''.018 + 19.2x$	97
	II–III	$+ .132 + 11.9$	206
	III–IV	$- .038 + 12.2$	41
	IV–I	$-0.111 + 18.9$	53
B	I–II	$-0.003 + 19.1$	51
	II–III	$+ .085 + 11.6$	62
	III–IV	$+ .062 + 11.5$	74
	IV–I	$-0.166 + 18.3$	70
C	I–II	$+0.011 + 19.6$	101
	II–III	$+ .114 + 11.6$	104
	III–IV	$+ .005 + 11.4$	104
	IV–I	$-0.203 + 18.5$	101

If we equate to 0 the cyclical sums of the group differences, we obtain the following three equations for the determination of x:

		Weight	
Series A	$-0''.035 + 62.2x = 0$	18	$x = +0''.000563$
B	$-0.022 + 60.5x = 0$	16	$x = +0.000364$
C	$-0.073 + 61.1x = 0$	26	$x = +0.001195$

These values of x correspond to the following values for the constant of aberration:

Series A	20.4566	weight,	18
B	4525	"	16
C	4695	"	26
Mean	20.4611	"	60

If we take $\pm 0''.16$ as the probable error of one observation of unit weight, the final mean result of our aberration observations is

Constant of Aberration = 20″.461 ±0″.006.

The following are the corrections necessary to reduce the declination systems of the several groups to the mean of all:

	Series A	Series B	Series C
	″	″	″
Group I	−0.056	−0.064	−0.094
II	− .063	− .060	− .061
III	+ .075	+ .029	+ .068
IV	+0.044	+0.095	+0.087

At the beginning of Series B a new pair of stars had to be substituted for one of the pairs in Group IV on account of precessional changes. The declination reductions cannot, however, have been sensibly affected thereby.

The following table gives the definitive latitudes from Series B and C, which may be used in continuation of the table in *A.J.* 101.

Definitive Latitudes.

Series B.

		$\varphi = 40° 48'+$	$\varphi-\varphi_0$	Weight
		″	″	
1894 July	1	27.114	−0.123	38
	16	.120	− .117	42
Nov.	15	.226	− .011	42
	29	.274	+ .037	46
Dec.	18	.367	+ .130	27
1895 Jan.	2	.305	+ .068	22
	15	.412	+ .175	59
Feb.	2	.380	+ .143	44
	14	.332	+ .095	44
	26	.425	+ .188	40
Mar.	10	.500	+ .263	20
	21	.346	+ .109	27
Apr.	8	.298	+ .061	33
	20	.353	+ .116	54
May	7	.354	+ .117	49
	18	.213	− .024	53
June	4	.184	− .053	32
	13	.257	+ .020	55
July	5	.217	− .020	50
	16	.286	+ .049	25
	28	.222	− .015	52
Aug.	10	.295	+ .058	21
	23	.103	− .134	50
Sept.	15	26.943	−0.294	26

Series B. — *Cont.*

		$\varphi = 40° 48'+$	$\varphi-\varphi_0$	Weight
		″	″	
1895 Oct.	1	26.996	−0.241	42
	18	27.111	− .126	62
Nov.	5	.119	− .118	54
	18	.063	− .174	36
Dec.	2	27.070	−0.167	43
Mean		27.237		

Series C.

		$\varphi = 40° 48'+$	$\varphi-\varphi_0$	Weight
		″	″	
1896 Jan.	14	27.474	+0.075	41
	28	.476	+ .077	60
Feb.	11	.542	+ .143	49
	22	.600	+ .201	46
Mar.	5	.560	+ .161	46
	17	.627	+ .228	42
	28	.464	+ .065	24
Apr.	9	.477	+ .078	40
	19	.367	− .032	37
May	5	.513	+ .114	64
	18	.532	+ .133	30
June	4	.551	+ .152	53
	20	.554	+ .155	33
July	1	.501	+ .102	54
	12	.437	+ .038	34
	31	.458	+ .059	52
Aug.	19	.379	− .020	64
Sept.	9	.331	− .068	24
	26	.240	− .159	29
Oct.	13	.135	− .264	37
	25	.142	− .257	59
Nov.	10	.193	− .206	63
	23	.118	− .281	25
Dec.	5	.232	− .167	39
	15	.314	− .085	16
	28	.219	− .180	29
1897 Jan.	8	.345	− .054	26
	25	.214	−0.185	46
Feb.	5	.387	−0.012	30
	18	.362	− .037	57
	28	.378	− .021	61
Mar.	10	.452	+ .053	41
	23	.283	− .116	11
Apr.	25	.583	+ .184	46
May	21	.565	+ .166	81
June	1	.376	− .023	18
	17	.573	+ .174	52
July	2	.595	+ .196	49
	20	.597	+ .198	28
Aug.	4	.522	+ .123	76
	22	.639	+ .240	46
Sept.	30	.503	+ .104	105
Oct.	16	.324	− .075	14
Nov.	4	.361	− .038	41
	16	.254	− .145	22
	26	.089	− .310	38
Dec.	10	.193	− .206	13
	26	27.100	−0.299	24
Mean		27.399		

PHOTOGRAPHIC OBSERVATIONS OF COMET *i* 1898 (BROOKS),

MADE WITH THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY,

By JAMES E. KEELER.

Having brought the 3-foot reflector, presented to the Lick Observatory by Mr. CROSSLEY, into fair working order, I have employed it in photographing the comet discovered by Mr. BROOKS on Oct. 20. With the assistance of Mr. H. K. PALMER I obtained photographs on eleven consecutive nights, from Nov. 4 to Nov. 14 inclusive. After Nov. 14 the work was discontinued, the maximum exposure which was allowed by the twilight on the one hand, and the construction of the mounting on the other, having been reduced to thirteen minutes.

The best photograph was obtained on Nov. 5, with an exposure of $1^h\ 10^m$. On this plate the extreme diameter of the coma is 0.25 inch = 4'.1. A very narrow, straight tail, extends to a distance of 1.4 inch, or 23'. In appearance the comet closely resembles Comet *b* 1894 (GALE) as photographed by BARNARD.

The tail is much less distinct on my other negatives, which received shorter exposures, and is barely perceptible on plates exposed for less than thirty minutes.

At the end of each exposure the driving-clock was stopped and the stars were allowed to trail on the plate for about two minutes. No trail was left by the comet.

With the aid of these trails the position angle of the tail was measured on six plates. The results are given in the following table, which may have some interest in connection with theories of the formation of comets' tails. In the table *r* is the computed position-angle of the radius-vector, and *t* the position-angle of the tail.

Date 1898	R.A.	Decl.	*r*	*t*	*r*—*t*
d h	h m s	° ′	° ′	° ′	° ′
Nov. 5 7	17 34 53	+17 12	53 55	48 37	+5 18
7 7	17 41 56	14 21	54 49	52	+2 49
8 7	17 45 7	12 32	55 40	52½	+3 10
9 7	17 48 0	10 51	56 19	53	+3 19
10 7	17 50 30	9 19	56 51	55	+1 51
12 7	17 55 3	+ 6 21	57 53	60	−2 7

A photograph was also taken by Mr. PALMER on Nov. 3, with the Crocker telescope. Willard (6-inch) portrait lens. The exposure was $1^h\ 17^m$. This photograph closely resembles those taken with the Crossley telescope, although the scale is of course very much smaller. The tail is about ¾° long.

OBSERVATIONS OF THE 1898 LEONID METEORS AND DISCOVERY OF A COMET (CHASE, Nov. 14) AT THE YALE OBSERVATORY.

By W. L. ELKIN.

Preparations were made for observing the Leonid shower this year and watch kept throughout the nights of November 12 to 16 inclusive, the main object being to secure photographic records of meteor trails. The apparatus at the observatory, an equatorial mounting with clockwork, carried six cameras with portrait-lenses of from 6 to 8 inches aperture, also two smaller ones. A similar apparatus, without clockwork, however, was put up at a station near Hamden, about two miles from the observatory in a northerly direction, and fitted out with four cameras with 5-inch lenses. This station was in charge of Dr. CHASE with an assistant, while at the observatory Mr. BROWN, Mr. SMITH and myself were on duty. Mr. LEWIS of Ansonia aiding for a part of the time.

On November 12 it cleared up only at about 16 hours (Eastern Standard Time) and plates were exposed in the observatory instrument for about an hour; 15 Leonids and 2 other meteors were seen by three observers in this hour, but 2 of which were in the field of the cameras. November 13 was completely overcast all night at New Haven. November 14 was clear throughout and the full programme carried out, plates being exposed at both stations from $11^h\ 15^m$ till $17^h\ 25^m$. Quite a display of the Leonids took place, then being noted by those in watch at the observatory (generally three of us):

From $11^h\ 15^m$	to $12^h\ 0^m$	Leonids:	10	others: 6
12 0	13 0		21	11
13 0	14 0		17	7
14 0	15 0		28	3
15 0	16 0		15	6
16 0	17 0		18	1
17 0	17 25		9	2
		Total:	118	36

Some 20 of them fell in or nearly in the field covered by the cameras.

November 15 was also clear, but the Leonid shower had decreased greatly, as can be seen from the numbers recorded, as follows:

From $11^h\ 15^m$	to $12^h\ 15^m$	Leonids:	1	others: 9
12 15	13 15		1	12
13 15	14 15		2	5
14 15	15 15		6	10
15 15	16 15		7	3
16 15	17 15		13	3
		Total:	30	42

of which about 10 may have been in the photographic field. November 16 was completely clouded over all night.

At present writing it is not possible to state definitely the complete result of the photographs. We have found about 16 trails so far on the plates, 4 meteors having been recorded at both stations, so that we hope some results of value may be derived from them.

The plates taken, over 60 in all, were not all developed and a systematic examination begun until November 21. Looking them over on that day Dr. Chase noticed a hazy object, elongated in the direction of the parallel, which showed apparent motion on successive exposures, the positions found by entering the object on the *Durchmusterung* charts being:

Nov. 14	12h 45m E.S.T.	R.A. 10h 4m.6	Decl. +23° 8′ (1855)
14	15 53	10 4.7	23 9
15	12 42	10 6.2	23 13
15	15 52	10 6.4	23 14

These plates were all taken with the same lens, a Voightlander of 6½ inches aperture and 27 inches focus, so that, suspecting some possible ghost and the night promising to be clear, we decided to defer notifying other observatories until we had secured further evidence. A second lens was directed to the same field, and Dr. Chase exposed two plates with each lens that night, and on development next day all four plates showed the object in the following plan on the Bonn maps:

Nov. 21 15h 30m E.S.T. R.A. 10h 16m.0 Decl. +23° 39′ (1855)

This position and the resulting daily motions of +1m.6 in R.A. and +4′.4 in Decl. were sent to Prof. Pickering at Harvard, who has informed us that the object was found on two and possibly three Harvard plates.

On November 21, while exposing the plates, Dr. Chase swept over the predicted place in the sky with the 8-inch Grubb refractor, but saw no hazy or comet-like object with certainty. On the plates its brightness is about that of an eleventh magnitude star, so that it possibly may have been too faint to attract notice by its appearing different in our telescope from a faint star.

Yale Observatory, 1898 *November* 24.

NOTE CONCERNING THE CENTRAL CONDENSATION OF THE *ANDROMEDA* NEBULA,

By WILLIAM J. HUSSEY.

On the evening of September 20, 1898, Professor Campbell and I carefully examined the central part of the *Andromeda* nebula with the 36-inch refractor, using powers of 270, 520 and 1000. We found the central condensation comparable in brightness to a star of the 11th to 12th magnitude. The most condensed part of the nebula was some 2″ in diameter, with no definite limits, but fading by imperceptible degrees to the general intensity of the surrounding nebula. It was not stellar; its appearance was quite unlike that of a neighboring star of about the same brightness, which appeared in the same low-power field. So far as I can judge, its appearance was the same as on previous occasions when I have examined it with the same telescope.

Professor Campbell examined the central condensation with a direct vision spectroscope, and found the spectrum continuous, with no evidence of bright lines, and in all probability the same as that of the rest of the nebula.

Lick Observatory, University of California, 1898 *November* 15.

OBSERVATIONS OF THE LEONIDS,

MADE AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,

By JAMES E. KEELER.

The Leonids were observed at Mt. Hamilton on several nights covering the period of apparition. On November 13th, when the greatest frequency was expected, two observers kept six-inch portrait lenses directed to the radiant from stations about 1500 feet apart, changing plates every hour to prevent over-exposure of comparison stars. Meteor tracks were charted, and counts made for determining the frequency, by four observers.

The results of the count made by Mr. C. D. Perrine are shown in the following table:

Date	Pacific Time	Interval	No. of Leonids	Av. No. per hour
	h m h m	h m		
1898 Nov. 11	13 20 – 15 10	1 50	8	4.4
12	12 55 – 14 55	2 0	10	5.0
13	13 0 – 16 30	3 30	38	10.9
14	13 38 – 13 53	0 15	8	43.8
14	14 24 – 16 0	1 36	73	
15	13 15 – 13 45	0 30	4	8.0
16	13 37 – 14 7	0 30	8	14.0
16	15 2 – 15 32	0 30	6	

The count of Mr. R. G. AITKEN is as follows:

Date	Pacific Time.	Interval	No. of Leonids	Av. No. per hour
	h m h m	h m		
1898 Nov. 11	12 9 – 15 20	3 11	6	1.9
12	13 45 – 15 45	2 0	24	12.0
13	12 30 – 16 20	3 50	27	7.1
14	13 32 – 14 40	1 8	26	28.8
14	14 40 – 15 58	1 18	11	

On November 13 four independent counts were made, each covering an interval of about four hours. A part of the results has been given above.

November 14, C. D. PERRINE, 10.9; R. G. AITKEN, 7.1; J. E. KEELER, 8.0; F. E. ROSS, 7.4. The numbers represent the average number of Leonids per hour.

It was remarked that the paths of some meteors, which had all the characteristics of Leonids, did not proceed from the usual radiant point, but passed some distance from it when produced backward.

A splendid meteor, 30 or 40 times brighter than *Venus* (PERRINE) was observed on November 14 at 13^h 46^m 44^s Pacific time. It came almost exactly from the radiant, and passed north of *δ Leonis*, where it disappeared.

With one exception, none of the meteors near the radiant were bright enough to leave trails on the plates which were exposed on November 13. A single trail was found at the extreme edge of one of the plates taken with the Crocker telescope. It was not photographed with the other instrument.

The charts and other records will be sent to Harvard College Observatory, for discussion in connection with similar records obtained elsewhere.

ELEMENTS OF COMET *j* 1898 (*CHASE*),

BY E. F. CODDINGTON AND H. K. PALMER.

Upon receiving the telegraphic announcement of the discovery of this comet, we examined carefully the photographic plates which we had exposed for *Leonid* meteors on November 13 and 14, and found that we had a faint image of the comet on all of them. Our exposures, being about an hour in length, were too short to give a perceptible trail, and the images were so faint that we would not have detected them had we not known of the comet's existence.

From Mt. Hamilton observations of November 23, 24, and 25 we have computed the following preliminary elements of this comet:

$$T = 1899 \text{ April } 10.6504 \text{ Gr. M.T.}$$

$$\begin{aligned} \omega &= 136^\circ\ 15'\ 13'' \\ \Omega &= 107\ \ 11\ \ \ 5 \\ i &= \ 33\ \ 41\ \ 42 \end{aligned}$$

$$\log q = 9.83386$$

$$\text{O}-\text{C}: \quad \Delta\lambda' \cos\beta' = +2'' \quad , \quad \Delta\beta'' = +1''$$

Mt. Hamilton, 1898 *Nov.* 28.

OBSERVATIONS OF COMET *j* 1898 (*CHASE*),

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

BY E. F. CODDINGTON.

1898 Mt. Hamilton M.T.	*	No. Comp.	☌ – * Δα	☌ – * Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s			
Nov. 23 17 8 11	1	8 , 8	−0 19.37	+8 1.8	10 21 18.07	+23 36 6.5	n9.117	0.333
24 16 34 34	2	14 , 8	+1 39.21	−3 40.8	10 23 15.70	+23 40 51.4	n9.294	0.355
25 17 15 25	4	8 , 9	+0 15.04	+3 21.3	10 24 17.50	+23 46 11.5	n9.020	0.321

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	10 22 3.42	+4.02	+23 28 27.7	−26.0	Becker, Berlin A.G. Catal. 4020
2	10 21 32.13	+4.06	+23 44 58.5	−26.3	Becker, Berlin A.G. Catal. 4014
3	10 26 45.40	+4.05	+23 50 33.0	−26.7	Becker, Berlin A.G. Catal. 4045
4	10 24 28.39	+4.07	+23 43 16.8	−26.6	10^M connected with *3

The brightness was estimated at 11 magnitude.

Mt. Hamilton, 1898 *Nov.* 28.

ELEMENTS AND EPHEMERIS OF COMET j 1898,

FROM A MEASUREMENT OF THE PHOTOGRAPHIC PLATES TAKEN AT THE YALE OBSERVATORY.

By FREDERICK L. CHASE.

I have obtained the following positions of the comet for 1875.0.

Gr. M.T.	α (1875.0)	δ (1875.0)
	h m s	° ′ ″
Nov. 14.7396	10 5 40.9	+23 3 17
21.8542	10 17 5.1	+23 32 11

from which and CODDINGTON's place for Nov. 26 I have computed the following elements and ephemeris.

ELEMENTS.

T = 1899 Jan. 4.9198 Gr. M.T.

$$\left.\begin{aligned}\omega &= 39°\ 59'\ 48''\\ \Omega &= 102\ 22\ 30\\ i &= 26\ 10\ 58\end{aligned}\right\}1898.0$$

$\log q = 0.415268$

Yale University Observatory, 1898 *Dec.* 3.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1898	α	δ	$\log\Delta$	Br.
	h m s	° ′		
Dec. 5.5	10 38 54	+24 42.0	0.3499	1.45
9.5	10 44 32	25 10.3	0.3403	1.52
13.5	10 49 58	25 41.2	0.3309	1.59
17.5	10 55 11	26 15.1	0.3216	1.66
21.5	11 0 7	+26 52.1	0.3125	1.73

Brightness Nov. 14 taken as unity.

The above orbit leaves for the middle observation the residuals: —

O—C = +1′ 38″ in longitude
O—C = + 3″ in latitude.

This disagreement may be due to a different point of the comet being selected for the photographic measurements than for the visual observations.

COMET j 1898.

This comet was discovered by Dr. F. L. CHASE, on Nov. 21, at the Yale Observatory, by an examination of four photographic plates taken there on Nov. 14, as recounted by Dr. ELKIN on p. 151 of this number. The object was also subsequently identified on two plates taken at the Harvard College Observatory, for which Prof. PICKERING gives the following positions:

Greenwich M.T.		α	δ	
	h m	h m s	° ′ ″	
1898 Nov. 14	21 40	10 5 55.9	+23 3 51	1875.0
14	22 28	5 58.7	3 57	

The comet was observed visually by CODDINGTON, on Nov. 23, 24 and 25, at the Lick Observatory, and these observations are given in detail on p. 154.

Orbits were computed by CODDINGTON and PALMER, and also by CHASE, and are given on pp. 153, 154. The latter finds it impossible to satisfy the observation of Nov. 21, and attributes the disagreement to possible difference in the points taken for photographic and visual measurement. In effect there is a systematic deviation from his parabola, not only of this but also of the positions on Nov. 23 and 24. ED.

Since the above was placed in type, and just before going to press, the following observation, taken by Mr. WENDELL at the Harvard College Observatory, has been received from Prof. PICKERING:

1898		α	δ
	h m s	h m s	° ′ ″
Dec. 7	14 12 31 Cambr. M.T.	10 40 41.15	+24 57 52.6

A remeasurement of the photographs, communicated by Prof. PICKERING, gives the following slight corrections to the above positions:

		$\Delta\alpha$ =	$\Delta\delta$
Nov. 14	1st plate,	+0.6 s	−6″
	2d plate,	+0.2	+3

These positions of Nov. 14 and Dec. 7, combined with that of Nov. 25 at Lick, give the following orbit, by which the middle place is represented as follows:

$$\text{O—C}, \quad \Delta\lambda\cos\beta = +1''.9 \quad , \quad \Delta\beta = +0''.4$$

ELEMENTS.

T = 1898 Sept. 18.132

$$\left.\begin{aligned}\omega &= 3°\ 51'\ 57''.4\\ \Omega &= 95\ 52\ 17.1\\ i &= 22\ 29\ 58.0\end{aligned}\right\}1898.0$$

$\log q = 0.358248$

EQUATORIAL COORDINATES, 1898.0

$$\begin{aligned}x &= [9.966007]\,r\,\sin(190°\ 13'\ \ 2''.2+v)\\ y &= [9.974676]\,r\,\sin(108\ 32\ 31.1+v)\\ z &= [9.703260]\,r\,\sin(\ 55\ 29\ 46.1+v)\end{aligned}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1898	α	δ	$\log\Delta$	Br.
	h m s	° ′		
Dec. 9.5	10 42 39	+25 10.5	0.3054	1.10
11.5	44 57	25 25.7		
13.5	47 10	25 41.5	0.2998	1.11
15.5	49 19	25 57.7		
17.5	51 21	26 14.4	0.2947	1.12
19.5	53 17	26 32.2		
21.5	55 6	26 50.4	0.2940	1.13
23.5	56 50	27 9.2		
25.5	58 27	27 28.6	0.2851	1.14
27.5	10 59 57	27 48.6		
29.5	11 1 22	+28 9.2	0.2810	1.15

ED.

A DETERMINATION OF THE ORBIT OF COMET 1895 II,

By HERBERT R. MORGAN.

The elements here given of the orbit of Comet 1895 II were obtained by the method of least squares from seven normals. The dates for the normals and the residuals between the observed positions and the positions computed from these elements are given in the following table. The third and fifth columns of the table give the number of observations used in each normal.

Perturbations were computed for all the planets except *Mars*, which at that time was on the opposite side of the sun from the comet.

All observations published, so far as I am aware, were employed, except a right-ascension observed at Washington August 22 (O−C = −8ˢ.73), and two declinations observed at University Park, Nov. 8 (O−C = −54″.6 and −63″.0).

In the determination of these elements I was assisted, at first, by Mr. OTTO DUNKEL, and afterwards, by Mr. E. O. EASTWOOD, the whole work being performed under the general supervision of Professor STONE, the Director of the Observatory.

Leander McCormick Observatory, 1898 *June* 1.

RESIDUALS (O−C).

Date.	$\Delta\alpha$	No. of Obs.	$\Delta\delta$	No. of Obs.
	″		″	
1895 Aug. 27.0	− 1.20	58	+0.79	58
Sept. 23.0	+ 2.40	110	+0.37	111
Oct. 17.0	− 3.00	83	−1.68	82
Nov. 15.0	− 5.55	33	−0.16	31
Dec. 13.0	+ 3.60	27	+1.67	26
1896 Jan. 6.5	+ 5.55	10	+6.10	8
Feb. 3.5	+16.50	3	+9.77	3

ELEMENTS.

Epoch, 1895 Aug. 24.5, Greenw. M.T.

Mean Equinox and Ecliptic 1895.0

$$\begin{aligned} M &= 0^\circ\ 30'\ 10''.75 \\ \omega &= 167\ 46\ 9.96 \\ \Omega &= 170\ 18\ 24.97 \\ i &= 3\ 0\ 26.71 \\ \varphi &= 40\ 43\ 47.25 \\ \mu &= 491''.5091 \\ \log a &= 0.5723167 \end{aligned}$$

ORBIT OF THE SMALL PLANET *DQ*.

By S. C. CHANDLER.

All the available observations of *DQ* have been corrected for parallax and aberration, and united into the following normal places:

1898	Obs.	Obs'd Normals, Eq. 1898.0 α	δ	O−C α	δ
		h m s	° ′ ″	s	″
Aug. 17.5	35	21 20 50.89	−6 21 27.3	−0.02	+0.7
24.5	26	21 8 16.15	−6 18 7.1	−0.15	+3.3
Sept. 1.5	19	20 55 35.58	−6 18 12.6	+0.04	+1.7
13.5	11	20 41 54.33	−6 21 1.2	−0.11	−0.3
23.5	14	20 36 19.66	−6 20 43.0	+0.05	−0.5
Oct. 11.5	2	20 39 2.16	−6 2 3.1	+0.30	−1.6
Nov. 11.5	4	21 12 34.47	−4 5 16.6	+0.01	−6.1
26.51707	1	21 37 13.57	−2 22 19.6	+0.02	−0.7

I am indebted to the directors of the observatories at Mt. Hamilton, Washington and Harvard College, for the communication of observations by HUSSEY (Nov. 6), FRISBY (Nov. 11) and WENDELL (Nov. 11 and 16). These form the seventh normal. The observation of Nov. 26 is by BARNARD, who also kindly sent data for thirteen other dates, in September and October. The deviations O−C are from the following orbit, computed from the first, fifth and eighth places given above.

Epoch 1898 Aug. 31.5 Gr. M.T.

$$\begin{aligned} M &= 221^\circ\ 45'\ 45''.6 \\ \omega &= 173\ 33\ 32.5 \\ \Omega &= 303\ 29\ 45.1 \\ i &= 10\ 19\ 27.2 \\ \varphi &= 12\ 52\ 32.8 \end{aligned} \quad \left.\begin{matrix}\omega\\ \Omega \\ i\end{matrix}\right\} 1898.0 \qquad \begin{aligned} \mu &= 2014''.6326 \\ \log a &= 0.1638739 \\ &\text{Period 643.29 days.}\end{aligned}$$

EQUATORIAL COORDINATES, 1898.0.

$$\begin{aligned} x &= [9.9946078]\, r \sin(211^\circ\ 31'\ 48''.0 + v) \\ y &= [9.9414945]\, r \sin(116\ 28\ 17.3 + v) \\ z &= [9.7080782]\, r \sin(137\ 1\ 0.3 + v) \end{aligned}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1898	α	δ	log Δ	Mag.
	h m s	° ′ ″		
Dec. 4.5	21 52 51.8	−1 14 37		
6.5	21 56 18.3	0 56 23	0.1409	12.5
8.5	22 0 48.6	0 37 37		
10.5	4 52.6	−0 18 15	0.1480	12.5
12.5	9 0.3	+0 1 31		
14.5	13 11.5	0 21 52	0.1544	12.5
16.5	17 26.3	0 42 45		
18.5	21 44.5	1 4 8	0.1605	12.6
20.5	26 6.2	1 26 0		
22.5	30 31.3	1 48 22	0.1663	12.6
24.5	34 59.6	2 11 12		
26.5	39 31.1	2 34 30	0.1716	12.6
28.5	44 5.7	2 58 11		
30.5	22 48 43.6	+3 22 24	0.1766	12.6

THE *LEONID* METEOR SHOWER OF 1898,

By EDWIN F. SAWYER.

The watch for the advance guard of the *Leonid* meteor shower due next year, was begun on Nov. 11 and continued until the 18th, although opportunities for observing the shower only presented themselves on the 11th, 12th and 14th, and for a short time on the 15th, on the other nights the sky remaining persistently overcast. On all occasions the center of observations was the sickle in *Leo*, and the view restricted to one-sixth of the visible heavens. On the 11th, from 14^h to 15^h, only three meteors were seen, none being *Leonids*. On the 12th, from 17^h to $17^h\ 30^m$, only one faint meteor was observed, not a *Leonid*. On the 14th the watch was quite successful and was prolonged three hours from 13^h to 16^h with the results given below. On the 15th, from $11^h.45$ to $12^h.15$, only one was seen, not a *Leonid*.

Limits of Watch B.M.T.	Duration	Meteors Seen		
		Leonids	Others	Total
h m h m				
13 0 – 13 30	30	9	2	11
13 30 – 14 0	30	5	1	6
14 0 – 14 30	30	7	2	9
14 30 – 15 0	30	7	1	8
15 0 – 15 30	30	8	4	12
15 30 – 16 0	39	6	2	8
	180	42	12	54

Per cent. of *Leonids*, 78.0.

Brighton, 1898 *November* 20.

The magnitudes of those recorded were as follows:

	>1M	1M	2M	3M	4M<	Total
Leonids	4	4	10	11	13	42
Others	0	1	1	3	7	12
Total	4	5	11	14	20	54

In mapping the meteor tracks, attention only was given to those with short paths accurately observed near the radiant center, and only five such were noted, which gave a well determined center as at R.A. 148°.75; Decl. +22°.25.

METEOR TRACKS MAPPED.

No.	Boston M.T.	Mag.	Observed Path From R.A.	From Decl.	To R.A.	To Decl.	Length of Path	Wt.
	h m		°	°	°	°		
1	13 24	3	154	+24.5	155.5	+25	2	4
2	13 59	4	155	+25¾	157	+27	2	4
3	14 1	>1	161.5	+18.5	164	+17¾	3	3
4	14 43	3	147.5	+14	147¼	+12	2	3
5	15 3	1	143	+9¼	142	+7	3	3

The bright meteors were of a decidedly green color, with persistent streaks, in one case lasting half a minute. There appeared to be no increase in the number observed from hour to hour during the watch.

NEW ASTEROIDS.

		1898	M.T.		α	δ	Daily Motion	Discoverer
	M		h m		h m s	° ′	s ′	
DU	12	Nov. 8	9 57.6	Nice	2 49 36	+15 31	−60 −2	Charlois
DV	12	Nov. 6	11 18.0	Heidelberg	3 10 8	+20 50		Wolf, Schwassmann
"		13	8 16.0	"	3 4 36	+18 56		
DW	12	Nov. 6	11 18.0	"	3 4 40	+18 15		Wolf, Villiger
"		13	8 16.0	"	2 58 40	+17 7		
DX	12	Nov. 6	11 18.0	"	3 2 24	+17 15	−44 −9	Wolf, Villiger
DY	13	Nov. 13	12 54.0	"	3 39 0	+17 59		Wolf, Villiger
"		18	10 52.0	"	3 34 48	+17 38		
DZ	12	Nov. 19	10 26.0	"	3 20 16	+19 2	−60 −5	Wolf, Villiger
EA	12.5	Nov. 19	13 39.0	"	2 57 12	+15 30	−44 −9	Wolf, Villiger

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NOTE ON THE MASS OF MERCURY.

By G. W. HILL.

Desiring to make some investigations on the secular perturbations of the solar system, it was necessary to choose values for the masses of the planets. *Mercury* gives the most difficulty in this respect, the values attributed to its mass being so discrepant. They have been derived from its action on *Venus* or on ENCKE's comet. To weight them and so take a mean is a method of treatment which does not recommend itself. Under these circumstances it has seemed to me that a value of the mass deduced solely from analogical considerations might be acceptable.

If there is any truth in the nebular hypothesis, the materials forming the masses of the four planets *Mercury*, *Venus*, the *Earth*, *Mars* and the *Earth's* moon ought to have approximately the same chemical constitution. Now the matter composing the outside layer of the *Earth* has a density about 2.55 (that of water being unity) while the mean density is 5.67. We hence infer that the density varies in the interior through the effect of pressure, and the phenomena connected with the rotation of the *Earth* are very well satisfied by what is known as LEGENDRE's law of density $\rho = k\dfrac{\sin mr}{r}$; where ρ denotes the density and r the distance of the matter considered from the center of the *Earth*, while k and m are constants, the latter showing the degree of compressibility. Without making a violent hypothesis this law may be extended from the *Earth* to the other four bodies under consideration, m being supposed the same for all, while k may be different for each. Knowing the masses of all the bodies but *Mercury*, we may derive the value of k for each of four different cases. Then we may attribute to *Mercury* a superficial density equal in succession to that of each of the four remaining bodies, and thus arrive at four different values for the mass of the former; and their agreement or disagreement will afford a criterion for the measure of success of the treatment.

I have compiled the following table of necessary data:

	Semi-diameter at distance 1	Reciprocal of mass	Log a	Log $\frac{R'}{R}$
Mercury	3.34″	. . .	9.58026	0.03020
Venus	8.546	408000	9.98827	0.31283
Earth	8.78	333470	0.00000	0.34632
Moon	2.393	27178000	9.43551	0.01636
Mars	5.054	3093500	9.76013	0.07321

The values of the semi-diameters are those which are employed in the *American Ephemeris*. By consulting HOUZEAU's *Vade-mecum de l'Astronome* it will be seen that astronomers are not well agreed upon these constants even in quite recent times. The value of the equatorial horizontal solar parallax has been diminished a little to make it correspond to the *Earth's* radius in latitude 35°. Taking this radius as the unit, the column headed "Log a" gives the logarithm of the radius a of each planet. Let R denote the density at the surface and R' the mean density. Then LEGENDRE's law of density gives the equation

$$\frac{R'}{R} = \frac{3}{ma}\left[\frac{1}{ma} - \cot ma\right]$$

which, in the case of the *Earth*, becomes

$$\frac{1}{m}\left[\frac{1}{m} - \cot m\right] = \frac{5.67}{3\times 2.55}$$

and from which $m = 2.5518 = 146°\ 12'\ 20''$. Having now the value of m as well as those of the several a, we compute the values of $\frac{R'}{R}$ for each planet, and their logarithms are inscribed in the last column of the table.

The details of the computation of the mass of *Mercury* severally from the four other bodies is thus shown:

	Venus	*Earth*	*Moon*	*Mars*
Log reciprocal of mass	5.61066	5.52306	7.43122	6.49045
Log $\left(\frac{a'}{a}\right)^3$	1.22403	1.25922	9.56575	0.53961
Log $\frac{R'}{R}$ of planet − Log $\frac{R'}{R}$ of *Mercury*	0.28263	0.31612	9.98616	0.04301
Log reciprocal of mass of *Mercury*	7.11732	7.09840	6.98613	7.07307
Mass of *Mercury*	$\frac{1}{13101500}$	$\frac{1}{12543000}$	$\frac{1}{9685750}$	$\frac{1}{11832400}$

The three planets give results quite accordant, but the one from the *Moon* is somewhat larger. Taking the mean of the four values we have for the mass of *Mercury* $\frac{1}{11634200}$.

STATEMENT OF THE THEORETICAL LAWS OF THE POLAR MOTION,

By SIMON NEWCOMB.

I have, during the past seven years, in the *Astronomical Journal* and elsewhere, stated several theorems relating to the variation of latitude which, when combined, would form the basis of as complete a theory of the subject as at present seems to me possible of construction. I have not, however, been able to put a complete paper on the subject into a satisfactory shape. As the exact relation of what I have said to the observed motion of the pole may not be entirely clear, I shall ask leave to state the conclusions derived from pure theory, without respect to the question of their agreement with observation.

1. Considering the earth as an elastic solid, covered wholly or partly by an ocean and an atmosphere, in a state of rest, the only motion of the pole would be the so-called Eulerian motion, consisting of a revolution of the axis of rotation around a certain mean pole of Figure P_0. This revolution would take place in a circle if the equatorial moments of inertia were equal; in an ellipse if unequal. In the actual earth there is not likely to be such a difference of these moments of inertia as to give rise to a sensible ellipticity in the motion. The period of the motion cannot be determined from theory, because the mean elasticity of the earth is unknown. But it cannot be so short as 430 days unless the earth is more rigid than steel.

2. The Eulerian motion as thus described, is subject to modifications by movements of matter on the earth's surface. These changes are of two kinds, statical and dynamical.

3. The statical changes are such as arise from the annual deposit of snow on the continents. These have no direct effect on the Eulerian motion, but only change it by altering the position of the pole P_0, thereby causing the instantaneous motion of the axis R of revolution to change its direction or its velocity. These changes being annual, their result will be represented by an annual term in addition to the regular Eulerian motion. Owing to the approximate symmetry of the American and Oceanic continents in the Northern hemisphere, it does not seem likely that the assymmetry of the snow-fall during winter could produce an annual term exceeding three or four hundredths of a second.

4. The dynamical causes are atmospheric and oceanic currents. Were these currents invariable, and were the earth circular, the pole would, in consequence, revolve steadily and invariably, according to the law stated in *A.J.*, Vol. XVI, p. 81. The earth being a spheroid, the cause in question so acts as to displace the center of the Eulerian motion from the actual pole P_0 to such a point P' that, if the pole of revolution R were at P', the dynamical motion in question would be exactly annulled by the Eulerian motion of R around P_0. The Eulerian motion will then take place around P' as if this were the pole of figure.

5. Were the currents in question steady throughout all time, the pole P' would remain invariable. But they are subject to annual variations, the possible amount of which can be only roughly estimated, and the varying momental axis of which must remain absolutely unknown. We must therefore conclude that the virtual pole P' is subject to an annual change, the *a priori* determination of which is impossible.

6. Were the annual changes in question the same in every year, the actual revolution of the pole would be represented by two periodic terms, the one having the Eulerian period and the other a period of one year.

7. The annual meteorological changes not being the same from year to year, but yet being invariable in the general average, it follows that the general character and magnitude of the annual term will be permanent, as will also be the period of the Eulerian term. But the effect of accidental differences in the annual meteorological movements from year to year will be to produce changes in the amplitude of the Eulerian motion. Each such change will be permanent in its nature, but constantly subject to increase or diminution by subsequent changes. Hence the amplitude will be subject to slow changes from time to time, which do not admit of prediction, while the apparent period will be subject to small irregular oscillations round a mean value.

Owing to the impossibility of setting exact limits to the possible annual changes in atmospheric currents, it is impossible to say absolutely that any conclusions of this theory are at variance with the deductions from observation by Mr. CHANDLER, as found in the *Astronomical Journal.* Whatever motions be observed in the pole, we may assume atmospheric currents which would give rise to them. At the same time, we may set more or less probable limitations to these changes. Considering the probability of the currents in question changing between certain limits, I would lay down the following statements:—

α. It is quite within the limits of ordinary probability that the coefficient of the annual term should amount to 0″.10. But the probability rapidly diminishes when we suppose it to have a larger value than this.

β. It is extremely improbable, one might say it is incompatible with any probable law of change in the atmospheric movements, that the annual revolution should be in a markedly elliptic path. That is to say, Mr. CHANDLER's conclusion that the annual term is a very elongated ellipse, is not easily explicable by the probable action of any known cause. The question whether the ellipticity which he finds is real and not due to errors of observation arising from annual and diurnally changing causes, is foreign to the purpose of this paper.

I quite agree with Mr. CHANDLER as to the eminent desirability of determining the actual polar motion from observations, with entire disregard of any theory. But I think it would be a mistake to conclude that, having laid down these motions, and having approximately represented them by empirical formulas, such formulas are to be taken as expressing the actual law of the motion, irrespective of their agreement with theory.

SUPPLEMENTARY NOTE ON THE DEVELOPMENT OF THE PERTURBATIVE FUNCTION,

By ALEXANDER S. CHESSIN.

In a previous note (See No. 442) the author has indicated a method for computing the terms in the development of the perturbative function by which a great economy of work is obtained. While the formulas given in that note referred chiefly to Prof. NEWCOMB's form of development it has been already stated that the method applies as well to LEVERRIER's development. This statement will be illustrated here by an example. In this connection it may be well to remark that Prof. NEWCOMB's development of the perturbative function in terms of the mean anomalies is directly reducible to LEVERRIER's, while the method used by Prof. NEWCOMB to arrive at this development is by far more elegant, and at the same time more practical than LEVERRIER's. To make it clearer, to every coefficient in LEVERRIER's development corresponds one in Prof. NEWCOMB's which differs from the former only in that derivatives with regard to $\log a$ are used instead of derivatives with regard to a. Thus, the terms of the class 0 in Prof. NEWCOMB's development are of the form

$$P \cos \{(i+m)\,g'-(i+n)\,g+iw'-iw\}$$

and those in LEVERRIER's are of the form

$$N \cos \{(i+m)\,l'-(i+n)\,\lambda-m\varpi'+n\omega\}$$

where

$$\lambda = l+\tau'-\tau$$
$$\omega = \varpi+\tau'-\tau$$

and g, g' denote the mean anomalies of the disturbed and disturbing planets; w, w' the distances of the common node of the two planets from the respective perihelia; l, l' the mean longitudes; and τ, τ' the longitudes of the common node of the two planets measured on their respective orbits. Then we have

$$w = \varpi-\tau \quad ; \quad w' = \varpi'-\tau'$$
$$l' = \varpi'+g' \quad ; \quad \lambda = \varpi+g+\tau'-\tau$$

and therefore,

$$(i+m)\,l'-(i+n)\,\lambda-m\varpi'+n\omega = (i+m)\,g'-(i+n)\,g+iw'-iw$$

Hence we must have $P = N$, and as both P and N are developed in powers of the eccentricities e, e', the terms in LEVERRIER's and in NEWCOMB's developments become at once comparable. In fact the coefficients of the several powers of e, e' will differ *only* in that the derivatives with respect to a are used by LEVERRIER, and with respect to $\log a$ by Mr. NEWCOMB. Now, as it is a simple operation to pass from one to the other, Professor NEWCOMB's *development could be directly obtained from* LEVERRIER's.

While in this manner the *actual* development of Prof. NEWCOMB could hardly be called distinct from LEVERRIER's, it presents, as remarked above, an important advantage over the latter, namely, *in the method of obtaining it.*

Indeed, by this method every symbolic term is expressed in function of symbolic terms of lower orders, which furnishes a means for the direct extension of the development to terms of higher order. Nor is this the only feature which marks the superiority of Mr. NEWCOMB's method. But it is not the purpose of this note to discuss this point. The author intended only to show that in their final form LEVERRIER's and NEWCOMB's developments were identical save for the difference of using derivatives with respect to a or $\log a$. This fact being established the formulas given by the author in the note referred to above are at once applicable to LEVERRIER's development. To give an illustration, we find in Prof. NEWCOMB's development the following expression for the symbolic coefficient $II^{\,1}_{\,0}$.

$$
\begin{aligned}
92160\; H^7_5 = &\ (128\,i^7 - 2400\,i^6 + 17800\,i^6 - 66790\,i^4 + 134246\,i^3 - 138970\,i^2 + 59570\,i) \\
&+ (320\,i^6 - 5232\,i^5 + 33140\,i^4 - 104095\,i^3 + 172821\,i^2 - 147149\,i + 50195)\,D \\
&+ (288\,i^5 - 3840\,i^4 + 19030\,i^3 - 45045\,i^2 + 55026\,i - 30679)\,D^2 \\
&+ (80\,i^4 - 600\,i^3 + 995\,i^2 - 175\,i + 326)\,D^3 \\
&+ (-40\,i^3 + 570\,i^2 - 2270\,i + 2515)\,D^4 \\
&+ (-36\,i^2 + 285\,i - 520)\,D^5 \\
&+ (-10\,i + 39)\,D^6 - D^7
\end{aligned}
$$

to which corresponds in LeVerrier the term

$$
\begin{aligned}
(379)^{(i)} = &\ \tfrac{1}{360}\,(64\,i^7 - 1200\,i^6 + 8900\,i^5 - 33395\,i^4 + 67123\,i^3 - 69485\,i^2 + 29785\,i)\,A_0 \\
&+ \tfrac{1}{720}\,(320\,i^6 - 4914\,i^5 + 29380\,i^4 - 85705\,i^3 + 129305\,i^2 - 93943\,i + 21875)\,A_1 \\
&+ \tfrac{1}{60}\,(48\,i^5 - 600\,i^4 + 2825\,i^3 - 6435\,i^2 + 7271\,i - 3125)\,A_2 \\
&+ \tfrac{1}{24}\,(16\,i^4 - 168\,i^3 + 703\,i^2 - 1114\,i + 1125)\,A_3 \\
&+ \tfrac{1}{3}\,(-4\,i^3 + 21\,i^2 - 7\,i - 50)\,A_4 \\
&+ \tfrac{1}{2}\,(-12\,i^2 + 45\,i - 25)\,A_5 \\
&+ (-10\,i + 18)\,A_6 - 7\,A_7
\end{aligned}
$$

Instead of the first of these two formulas the method proposed by the author furnishes the following much simpler one,

$$
\begin{aligned}
H^7_5 = &\ 7H^7_7 + 2\,(i-6)\,H^6_6 + \tfrac{1}{4}\,(-3i+10)\,H^5_5 \\
&+ \tfrac{1}{12}\,(-3i+4)\,H^4_4 + \tfrac{1}{24}\,(-4i+3)\,H^3_3 \\
&+ \tfrac{9}{320}\,(-5i+2)\,H^2_2 + \tfrac{1}{45}\,(-6i+1)\,H^1_1 - \tfrac{625}{2304}\,i
\end{aligned}
$$

In place of this we would have for LeVerrier's development the formula

$$
\begin{aligned}
(379)^{(i)} = &\ 7\,(450)^{(i)} + 4\,(i-6)\,(434)^{(i)} + (-3i+10)\,(378)^{(i)} \\
&+ \tfrac{2}{3}\,(-3i+4)\,(336)^{(i)} + \tfrac{2}{3}\,(-4i+3)\,(240)^{(i)} \\
&+ \tfrac{9}{16}\,(-5i+2)\,(172)^{(i)} + \tfrac{64}{45}\,(-6i+1)\,(50)^{(i)} \\
&- \tfrac{625}{18}\,i\,(1)^{(i)}
\end{aligned}
$$

which can be directly verified. It has been derived here from the formula immediately preceding it, and by comparing, as explained above, LeVerrier's and Newcomb's developments, which gives

$$
\begin{aligned}
H^7_7 A_0 &= (\tfrac{1}{2})^7\,(450)^{(i)} \\
H^6_6 A_0 &= (\tfrac{1}{2})^6\,(434)^{(i)}
\end{aligned}
$$

and so on. The factors $(\frac{1}{2})^7$, $(\frac{1}{2})^6$, . . . appear because the development of LeVerrier contains the powers of *half* the eccentricities, while in Prof. Newcomb's development the powers of the eccentricities themselves appear.

New York, 1898 *Oct.* 1.

THE SMALL PLANET *DQ* AT THE OPPOSITIONS OF 1893–94 AND 1896,

By S. C. CHANDLER.

The important use to be made of the planet *DQ* in the future in the solution of various astronomical problems, and particularly the most immediate service for which it will be called upon at the coming opposition of 1900–01 in the determination of the solar parallax, make the problem of perfecting its theory one of the highest exigency. As a help towards its solution it is an obvious suggestion that the most efficient means would be a recovery of observations of the planet at the bright opposition, near perihelion, in 1893–94; and it has seemed probable that existing impressions of it might be found on the numerous photographic plates taken in many places, for various other purposes, at that time. Especially likely to yield such material were the photographs for the astrographic charts and catalogue then under way, and the large store-house of plates accumulated at the Harvard College Observatory. It appeared to me that even at this early date a search for such observations might be hopefully undertaken. To contribute a small part toward such a desirable result, by making the necessary preliminary calculations by means of which such a search could be instituted, if those in possession of the plates would undertake it, I communicated with Prof. Pickering on the subject of its prosecution. He was fully alive to its importance, and desired and intended to begin it so soon as the requisite means in the way of trustworthy ephemerides should be forthcoming.

It was in behalf of this project that I was led to the calculation of the elements given in *A.J.* 451, as a first approximation. An observation of Dec. 3, received from Prof. Barnard, showed a deviation of $-0^s.22$ and $-6''.4$ (O−C). This and the deviations from the normals there given seemed to show that no serious correction to the mean motion need be feared, and that the orbit would prove adequate for the purpose in view without further amendment. Of course the difficulty attending the proposed search was due largely to the uncertainty of the element μ. This differs by several seconds, between $2010''$ and $2015''$, in the various elements already published. Now an error of $1''$ in the mean motion corresponds to $6°$ or $7°$ in the geocentric place at the beginning of 1894. As a matter of fact these various orbits differed by a couple of hours in right-ascension and many degrees in declination, among themselves, in the places they assigned to the planet about the time in question. But I felt somewhat confident that my determination of μ might be relied upon within $1''$. As a matter of fact the correction, since indicated by the result of the search to be described in this paper, is only $+0''.6$.

I accordingly prepared an ephemeris for the perihelion

opposition of 1894, extending from October 1893 to April 1894, giving also at various points of the trajectory an indication of the line of uncertainty depending on the uncertainty in the mean motion. This was sent to the Harvard College Observatory, where the hunt was at once begun. The result was at first unsuccessful. I wish here to express my appreciation of the patience and willingness to continue the investigation, under such discouraging circumstances, evinced by both Prof. PICKERING and Mrs. FLEMING. As an illustration of the vexatious sources of confusion, tending to mislead — and there were many others — a bright object of the 9th magnitude was found at about $8^h\,34^m$, $+50°.4$, or 27^m following and $2°.6$ south of the predicted place, thus almost exactly the amount and direction which an error of $-1''$ in μ would give. While this was possible I felt convinced that it was in the opposite direction from that in which the planet would be, and was actually ultimately found, and fortunately no further time was wasted upon what finally proved to be a new variable star.

Since it was found that there were numerous plates taken at Arequipa in 1896, in the neighborhood of the planet, a searching ephemeris was prepared also for that opposition, notwithstanding the discouraging circumstance of the comparative faintness of the planet at that time, between 11^M and 12^M. The outcome of this step was that an object was detected on four plates, for which the deviations from the ephemeris were, approximately,

	O—C	
	m s	′
1896 April 6	−0 36.0	−4.8
June 4	−1 16.7	−5.9
June 5	−1 16.4	−5.6
June 5	−1 16.7	−5.8

This evidence was conclusive of the identity with the planet sought for, and gave at once the means of correcting the orbit and resuming the hunt at the 1893–94 opposition. Computation showed that a correction to μ of $+0''.60$ was required. The other elements were also slightly varied, as follows:

Epoch 1898 Aug. 31.5 Gr. M.T.

$$
\begin{aligned}
M &= 221°\ 35'\ 15''.6 \\
\omega &= 177\ 37\ 56.0 \\
\Omega &= 303\ 31\ 57.1 \quad 1898.0 \\
i &= 10\ 50\ 11.8 \\
\varphi &= 12\ 52\ 9.8 \\
\mu &= 2015''.2326 \\
\log a &= 0.1637876
\end{aligned}
$$

Period 643.10 days

With a new ephemeris based on this orbit, a revision of the 1894 plates now resulted in the detection of objects, undoubtedly the planet, on at least six plates. For these the deviations from the above orbit were as follows:

	O—C	
	s	
1893 Dec. 19	−3.5	0.0
Dec. 27	−0.7	−0.3
1894 Jan. 1	−1.9	−1.0:
Feb. 16	+5.1	−1.0
April 16	+7.6	+0.2
April 18	+7.4	+0.4

It is interesting to note that the range covered by these identifications is four months and 95° of heliocentric arc, during two months of which the planet was less than 0.20 distant from the earth, the nearest approach being only 0.153, which is practically as near as it can ever come. This emphasizes the great importance of these observations, which will furnish the means for an independent determination of the orbit, of very high precision, from this opposition alone. The bearing of this circumstance on the perfecting of the theory of the planet is manifest.

Prof. PICKERING informs me that a further search is more than likely to yield other observations in 1893–94, since the fund of plates is by no means exhausted. For this reason I do not deem it worth while to correct the above elements at present, but shall await the full extraction of the available material of the plates, when I shall determine the orbit definitively, including the perturbations, from all the oppositions observed. For the present the provisional orbit above given represents the observed path within such narrow limits, as is shown by the last table of residuals, that the ephemeris will perfectly serve for the identification of the planet. It is therefore given below for six months during which it was brighter than the tenth magnitude. The places are referred to the equinox of 1894.0. The constants for the equator are

1893.0

$$
\begin{aligned}
x &= [9.994591]\, r \sin (211°\ 34'\ 14''.3 + v) \\
y &= [9.941491]\, r \sin (116\ 30\ 15.1 + v) \\
z &= [9.708145]\, r \sin (137\ \ 4\ 42.6 + v)
\end{aligned}
$$

1894.0

$$
\begin{aligned}
x &= [9.994593]\, r \sin (211°\ 35'\ 5''.7 + v) \\
y &= [9.941482]\, r \sin (116\ 31\ 7.8 + v) \\
z &= [9.708168]\, r \sin (137\ \ 5\ 20.8 + v)
\end{aligned}
$$

EPHEMERIS FOR GREENWICH MIDNIGHT AND EQUINOX 1894.0.

1893	α (1894.0) h m s	δ (1894.0) ° ′	log Δ	Mag.
Oct. 27.5	5 56 22	+53 18.6	9.6713	9.86
31.5	6 8 15	54 15.0		
Nov. 4.5	20 3	55 4.8	9.6254	9.59
8.5	31 39	55 49.6		
12.5	43 0	56 28.4	9.5778	9.31
16.5	6 53 36	57 0.4		
20.5	7 4 18	57 25.1	9.5285	9.02
24.5	13 59	57 41.3		
28.5	7 22 48	+57 47.9	9.4772	8.73

	α (1894.0)	δ (1894.0)	log Δ	Mag.
1893	h m s	° ′		
Dec. 2.5	7 30 29	+57 43.8		
6.5	36 54	57 27.4	9.4240	8.43
10.5	41 52	56 56.6		
14.5	45 19	56 8.8	9.3692	8.13
18.5	47 15	55 1.5		
22.5	47 41	53 31.0	9.3141	7.87
26.5	46 44	51 34.2		
30.5	44 37	49 7.4	9.2615	7.55
1894 Jan. 3.5	41 34	46 7.8		
7.5	37 59	42 34.5	9.2170	7.31
11.5	34 15	38 28.9		
15.5	30 45	33 55.4	9.1890	7.16
19.5	27 46	29 1.3		
23.5	25 30	23 58.6	9.1850	7.14
27.5	24 6	19 0.1		
31.5	23 34	14 15.9	9.2065	7.25
Feb. 4.5	24 0	9 55.0		
8.5	25 20	6 1.3	9.2475	7.47
12.5	7 27 37	+ 2 37.3		

	α (1894.0)	δ (1894.0)	log Δ	Mag.
1894	h m s	° ′		
Feb. 16.5	7 30 46	− 0 18.0	9.2994	7.74
20.5	34 41	2 46.8		
24.5	39 17	4 51.6	9.3551	8.04
28.5	44 31	6 35.4		
Mar. 4.5	50 20	8 1.0	9.4111	8.35
8.5	7 56 41	9 10.7		
12.5	8 3 32	10 8.5	9.4654	8.65
16.5	10 48	10 55.3		
20.5	18 29	11 33.2	9.5175	8.94
24.5	26 30	12 4.0		
28.5	34 50	12 29.1	9.5672	9.23
Apr. 1.5	43 25	12 49.3		
5.5	8 52 15	13 5.8	9.6147	9.50
9.5	9 1 18	13 19.6		
13.5	10 34	13 31.3	9.6604	9.77
17.5	19 59	13 41.8		
21.5	9 29 33	−13 51.7	9.7043	10.03

Brightness 1898 Aug. 24.5 taken as $11^{\mathrm{M}}.5$ ($\log r = 0.2396$, $\log \Delta = 9.8722$.)

OBSERVATIONS OF MINOR PLANETS,

MADE AT THE DUDLEY OBSERVATORY, ALBANY, N.Y.,

By ARTHUR J. ROY.

Albany M.T.		✱	No. Comp.	Planet — ✱ Δα	Planet — ✱ Δδ	Planet's Apparent α	Planet's Apparent δ	log Δp for α	log Δp for δ
				(387) 1894 *AZ*.					
1896	h m s			m s	′ ″	h m s	° ′ ″		
Nov. 22	8 15 38	1	10	+0 17.00	+2 2.9	3 18 34.59	− 8 7 6.4	*n*9.478	0.818
				(175) *Andromache*.					
1897									
Jan. 24	10 21 56	2	6	+1 35.28	−1 9.5	8 51 46.90	+21 57 25.9	*n*9.404	0.542
31	14 1 42	3	9	−0 52.11	−4 53.9	8 46 2.85	+22 18 39.5	9.379	0.530
				(103) *Hera*.					
Jan. 24	10 46 54	4	6	+0 58.22	−5 47.6	9 20 29.44	+15 9 29.8	*n*9.397	0.637
30	13 49 21	5	10	−0 22.99	−4 30.2	9 15 13.73	+15 43 51.9	9.173	0.610
31	13 0 42	6	8	+0 15.86	+1 29.6	9 14 22.72	+15 49 23.5	8.813	0.600
Feb. 1	8 59 34	7	10	−0 46.93	+0 24.1	9 13 38.72	+15 54 4.8	*n*9.545	0.664
				(313) *Chaldaea*.					
Mar. 28	10 2 26	8	10	−1 8.90	−4 11.9	14 10 34.66	− 3 55 32.7	*n*9.554	0.793
Apr. 2	10 40 0	9	10	−0 13.54	−6 50.6	14 7 15.00	− 2 56 48.6	*n*9.447	0.793
3	11 33 39	9	10	−0 58.53	+5 19.3	14 6 30.02	− 2 44 38.7	*n*9.272	0.795
28	9 50 42	10	8	−2 8.15	+7 30.9	13 46 19.60	+ 1 32 48.2	*n*9.204	0.763
May 5	9 30 57	11	8	+2 53.72	−7 12.0	13 41 24.96	+ 2 21 19.0	*n*9.138	0.756
7	12 38 38	12	10	+1 42.94	−1 3.1	13 40 6.01	+ 2 33 20.7	9.350	0.756
				(334) *Chicago*.					
Apr. 2	9 53 36	13	10	−0 24.09	+9 27.4	13 13 15.50	− 1 50 11.3	*n*9.430	0.787
3	10 56 0	14	10	−0 10.67	+2 39.8	13 12 37.85	− 1 45 44.0	*n*9.201	0.789
18	8 56 8	15	12	−0 56.94	+4 45.4	13 3 43.19	− 0 46 50.3	*n*9.391	0.781
21	8 43 18	16	8	+2 4.90	+0 35.4	13 2 1.80	− 0 36 31.3	*n*9.389	0.780

Mean Places for 1896.0 and 1897.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	3 18 13.04	+4.55	− 8 9 31.5	+22.2	Paris 4034, etc.
2	8 50 8.96	+2.66	+21 58 40.6	− 5.2	Becker, A.G. Berlin 3597
3	8 46 52.18	+2.78	+22 23 38.6	− 5.2	" " " 3574
4	9 19 28.74	+2.48	+15 15 24.3	− 6.9	Auwers, " " 3799
5	9 15 34.11	+2.61	+15 48 29.3	− 7.2	" " " 3778, etc.
6	9 14 4.23	+2.63	+15 48 1.0	− 7.1	" " " 3767
7	9 14 23.01	+2.64	+15 53 47.9	− 7.2	" " " 3770
8	14 11 40.90	+2.66	− 3 51 1.3	−19.5	Glasgow I 3542, etc.
9	14 7 25.82	+2.72	− 2 49 38.1	−19.6	" " 3524, etc.
10	13 48 24.78	+2.97	+ 1 25 36.3	−19.0	A.G. Albany 4814
11	13 38 28.26	+2.98	+ 2 28 49.4	−18.4	" " 4784
12	13 38 20.08	+2.99	+ 2 31 12.0	−18.2	" " 4783
13	13 13 36.82	+2.77	− 1 59 19.3	−19.4	Königsberg (A.N. 74 247), etc.
14	13 12 45.75	+2.77	− 1 48 4.1	−19.4	" " " ..
15	13 4 37.27	+2.86	− 0 51 16.6	−19.1	Copeland and Börgen 3956
16	12 59 54.03	+2.87	− 0 36 47.6	−19.1	" " " 3944

*1 adopted p.m. $0^s.0000$ $-0''.222$. *9 adopted p.m. $-0^s.012$ $-0''.32$.

THE AREAL VELOCITIES IN THE ANNUAL COMPONENT OF THE POLAR MOTION,

By S. C. CHANDLER.

In *A.J.* 329 it was predicated that the annual component of polar motion conforms to the law of equal times for equal areas described by the radius-vector from the center of the ellipse. The proof of this was implicitly contained in the demonstration there given that the observed coordinates of that motion are harmonic functions of the time, since it then follows [*A.J.* 406, eq. (24)] that the double-area described in the unit of time is

$$\rho^2 d\beta = \frac{ab}{4}\, d\odot$$

thus a constant for all parts of the ellipse. It is desirable, however, that the proof of this proposition should be explicitly deduced directly from the observations in a manner which will make visible, by inspection, with what completeness they justify it. This I will briefly do. If we compute the values of the coordinates of the 427^d-term by the revised elements on p. 109, *A.J.* 446, and subtract them from the observed values of x, y, on p. 106, we get the coordinates x_2, y_2, for the annual term. My actual computation of these was not for the 50-day intervals of the table, but for each tenth of a year. These values were then converted to polar coordinates by $x_2 = \rho \sin \alpha$, $y_2 = \rho \cos \alpha$, where α is reckoned east from Greenwich. From these values of ρ and α we compute the double-areas of the triangles

$$[\rho\rho'] = \rho\rho' \sin(\alpha' - \alpha)$$

from each two consecutive values. This gives 64 values of $[\rho\rho']$, which, since $\beta = \alpha - \omega$, can be arranged in order of $\beta_0 = \frac{1}{2}(\alpha' + \alpha) - \omega$, the mean angle from the vertex, thus exhibiting the law of areas. These areas, if the proposition we are examining be true, must all be equal. They are given in 16 means of 4 each in the following table, which also contains the mean values of $\alpha' - \alpha = \beta' - \beta$.

April–October			October–April		
β_0	$[\rho\rho']$	$\beta'-\beta$	β_0	$[\rho\rho']$	$\beta'-\beta$
°			°		°
12	0.0035	14	192	0.0032	19
27	41	19	206	38	25
64	35	82	250	33	82
112	50	68	285	30	100
147	44	26	325	43	15
166	44	17	341	43	23
175	31	13	347	13	6
182	32	11	357	39	15

The mean value of the double-areas is 0.00364 with the mean error ±0.00019. For the two halves of the ellipse we have

April–October $[\rho\rho']$ =	0.0039 ± 2
October–April	0.0034 ± 3

from which there appears to be no appreciable dissymmetry dependent on season.

Arranging in order of $\beta' - \beta$ we get

$\beta'-\beta$	$[\rho\rho']$	Means		$\beta'-\beta$	$[\rho\rho']$	Means	
°				°			
6	0.0013	11°	0.0028	19	0.0041	23°	0.0041
11	32			23	43		
13	31			25	38		
14	35			26	44		
15	0.0039	17°	0.0040	68	0.0050	83°	0.0037
15	43			82	35		
17	44			82	33		
19	32			100	30		

Thus for the first twelve values, corresponding to a mean daily angular velocity of 0°.5, the pole being within an average angle of 17° from the major axis, the double-area

described in a tenth of a year is 0.0036; while for the last four values, corresponding to a daily angular velocity of 2°.4, or nearly five times as great, the pole being at an average angle of 21° from the minor axis, the double-area is practically the same, or 0.0037. The fact is therefore satisfactorily established, by pure induction from observation, that there is no sensible inequality in the areal velocities of motion in the annual elliptical component.

The mean value above, 0.00364, gives the area of the ellipse 0.0182, disregarding the difference between sectors and triangles, which for the intervals used are evanescent. The area given by the dimensions of the revised elements, $a = 0''.285$, $b = 0''.085$, is

$$\pi \frac{ab}{4} = 0.0183$$

Thus the mean dimensions are verified by an independent process.

OBSERVATION OF PLANET *DQ*,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 12-INCH EQUATORIAL,

BY PROF. E. FRISBY, U.S.N.

[Communicated by Prof. WM. HARKNESS, U.S.N., Astronomical Director.]

1898 Washington M.T.	No. Comp.	Planet — ✳ $\Delta\alpha$	Planet — ✳ $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s		m s	′ ″	h m s	° ′ ″		
Nov. 1 19 1 26.0	20 , 4	−2 30.80	−11 7.2	21 12 44.36	−4 4 33.9	9.537	0.766

Mean Place for 1898.0 of Comparison-Star.

α	Red. to app. place	δ	Red. to app. place	Authority
h m s	s	° ′ ″	″	
21 15 11.57	+3.59	−3 53 47.0	+20.3	Schjellerup 8624

OBSERVATIONS OF COMET *j* 1898 (CHASE),

MADE WITH THE 8-INCH REFRACTOR OF THE YALE OBSERVATORY AND CROSS-BAR MICROMETER,

BY F. L. CHASE.

1898 New Haven M.T.	✳	No. Comp.	☄ — ✳ $\Delta\alpha$	☄ — ✳ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Dec. 13 16 3 36	1	12	+2 37.10	+ 1 59.3	10 47 46.90	+25 43 55.8	n9.179	0.398
14 14 15 23	2	7	−1 30.91	−14 33.5	10 48 46.37	+25 51 1.0	n9.538	0.505
14 14 21 11	3	5	−1 32.60	+10 27.0	10 48 48.19	+25 51 14.9	n9.523	0.491
15 17 14 39	4	10	−0 39.12	−12 49.8	10 49 58.78	+26 0 42.4	7.653	0.360
15 17 33 41	5	8	−1 42.78	+12 12.5	10 49 59.72	+26 0 44.6	8.643	0.361

Mean Places for 1898.0 of Comparison-Stars.

✳	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	10 45 5.25	+4.55	+25 42 28.3	−31.8	Graham, Cambridge, A.G. Catal. 5520
2	10 47 10.89	+4.57	+26 6 9.7	−32.2	Graham, Cambridge, A.G. Catal. 5539
3	10 50 16.25	+4.54	+25 41 20.1	−32.2	Graham, Cambridge, A.G. Catal. 5556
4	10 50 33.31	+4.59	+26 14 4.8	−32.6	Graham, Cambridge, A.G. Catal. 5557
5	10 51 37.93	+4.57	+25 49 4.6	−32.5	Graham, Cambridge, A.G. Catal. 5565

Yale University Observatory, 1898 *December* 20.

CORRIGENDA.

No. 376, p. 128, obs. of Apr. 29, *for* +50° 15′ 56″.4 *put* +50° 15′ 33″.5.
No. 376, p. 128, Comp.-Star 6, *for* +50° 14′ 25″.7 *put* +50° 14′ 2″.8.
No. 446, p. 109, col. 2, line 13 from bottom, *for* +0″.007 (t—1894) cos ☉ *put* +0″.007 (t—1894) sin ☉.

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THE BENJAMIN APTHORP GOULD FUND.

On Nov. 17, 1897, the sum of twenty thousand dollars was given to the National Academy of Sciences, as Trustee, to establish a fund to be known as the BENJAMIN APTHORP GOULD FUND, in memory of the father of the donor, Miss ALICE BACHE GOULD, the income to be used to assist the prosecution of researches in astronomy, the administration of this income, in accordance with the terms of the Trust and of a letter of instructions from the donor, to be under the direction of the undersigned.

A sufficient available income has now accrued from the Fund to warrant beginning its distribution, and the Directors are prepared to receive and consider applications for appropriations. As a guide in framing such applications it is desirable to present briefly, but in close adherence to the exact terms of the Trust and of the letter of instructions accompanying it, the principal provisions to be regarded in the administration of the Fund.

The objects of the institution are, first, to advance the science of Astronomy; secondly, to honor the memory of Dr. GOULD by ensuring that his power to accomplish scientific work shall not end with his death. In recognition of the fact that during Dr. GOULD's lifetime his patriotic feeling and ambition to promote the progress of his chosen science were closely associated, it is preferred that the Fund should be used primarily for the benefit of investigators in his own country or of his own nationality. But it is further recognized both by the donor and the Directors that sometimes the best possible service to American science is the maintenance of close communion between the scientific men of Europe and of America, and that therefore, even while acting in the spirit of the above restriction, it may occasionally be best to apply the money to the aid of a foreign investigator working abroad.

The wish was also expressed by the donor that in all cases work in the astronomy of precision should be given the preference over any any work in astrophysics, both because of Dr. GOULD's especial predilection and because of the present existence of generous endowments for astrophysics.

Finally the BENJAMIN APTHORP GOULD FUND is intended for the advancement and not for the diffusion of scientific knowledge, and is to be used to defray the actual expenses of investigation, rather than for the personal support of the investigator during the time of his researches, without absolutely excluding the latter use under the most exceptional circumstances.

Application for appropriations from the income of this Fund may be made informally by letter to any of the Directors undersigned, stating the amount desired, the nature of the proposed investigation, and the manner in which the appropriation is to be expended. If favorably considered, a blank for formal application will be forwarded for signature, with the rules adopted by the Directors for the administration of the Fund, and to which the applicant will be expected to subscribe.

LEWIS BOSS,
SETH C. CHANDLER,
ASAPH HALL.

1899 *January* 1.

RESULTS OF ZENITH-TELESCOPE OBSERVATION AT THE FLOWER OBSERVATORY,

By C. L. DOOLITTLE.

The following summary of results derived from the series of zenith-telescope observations in progress at this place may be regarded as final. The declinations of some of the stars employed may hereafter be improved, but most of the material for their accurate determination now existing has been utilized.

Some of the elements of reduction have not been determined in a manner entirely satisfactory. This is particularly true of the temperature-coefficient. An apparently genuine value of this constant was derived from a considerable amount of material, but additional data did not confirm it. Moreover its introduction increased the probable error rather than otherwise.

No temperature-correction has therefore been employed, but the effort has been made to conduct the investigation in such a way as to eliminate this and similar sources of error.

For the arrangement of groups and method of procedure reference may be made to the preliminary determination of the Constant of Aberration, *A.J.* No. 428.

Two complete cycles in right-ascension are embraced in the following series. After some hesitation it was decided to reduce these separately both for aberration and adjustment of the groups for latitude.

In the determination of the constant of aberration which follows, with the exceptions mentioned, all of the combinations are of evening and morning series observed on the same night. The exceptions are two cases in the series of '96–'97, and three in that of '97–'98, where the observations combined were made on consecutive nights.

Assembling the results in groups embracing intervals of about ten days we have the values which follow.

		$\Delta\varphi$	Aberration	Wt.
		″	″	
1896 Oct. 10	IV–I	−0.218	+18.14	14
24		− .012	19.17	18
Nov. 2		− .016	19.36	9
16		− .270	+18.49	26
	Mean	−0.1559	+18.72	67
1897 Jan. 30	I–II	−0.020	+18.61	24
Feb. 21		− .075	19.11	26
Mar. 12		− .128	+17.99	14
	Mean	−0.0660	+18.68	64
May 14	II–III	+0.021	+12.89	27
28		+ .025	+13.51	33
	Mean	+0.0232	+13.23	60
July 9	III–IV	−0.299	+11.61	20
27		− .220	12.18	22
Aug. 5		− .262	12.42	15
12		− .128	12.18	14
23		−0.051	+11.40	19
	Mean	−0.1946	+11.93	90

		$\Delta\varphi$	Aberration	Wt.
		″	″	
1897 Oct. 11	IV–I	−0.213	+18.25	22
30		− .183	19.28	14
Nov. 29		− .210	+16.89	14
	Mean	−0.2038	+18.16	50
1898 Feb 3	I–II	−0.064	+18.88	20
11		− .012	19.21	12
27		+ .006	19.17	15
Mar. 9		−0.336	+18.08	18
	Mean	−0.1136	+18.79	65
Mar. 14	II–III	−0.052	+13.39	21
June 1		− .203	13.54	16
8		−0.127	+12.80	22
	Mean	−0.1209	+13.21	59
July 6	III–IV	−0.051	+11.67	21
20		+ .026	12.22	15
Aug. 6		− .077	12.45	13
15		−0.227	+11.30	8
	Mean	−0.0614	+11.94	57

Then $(20.4451.x)$ being the correction to Struve's constant of aberration we have

$$\begin{aligned} 18.72x - 0''.1559 &= 0\\ 18.68x - .0660 &= 0\\ 13.23x + .0419 &= 0\\ 11.93x - 0.1946 &= 0\\ \hline 62.56x - 0.3931 &= 0 \end{aligned}$$

$$\begin{aligned} 18.16x - 0''.2038 &= 0\\ 18.79x - .1136 &= 0\\ 13.21x - .1209 &= 0\\ 11.94x - 0.0614 &= 0\\ \hline 62.10x - 0.4997 &= 0 \end{aligned}$$

$x =$	0″.006283
Δ Aberration	0.1285
Struve	20.4451
Resulting value	20.5736

$x =$	0″.008047
Δ Aberration	0.1645
Struve	20.4451
Resulting value	20.6096

The results of 1898 March 8th and 9th appear to be abnormal. They are as follows:

	I . φ	Obs.	II . φ	Obs.	Δφ
March 8	″ 1.73	10	″ 2.19	3	″ —.46
9	1.88	10	2.36	10	—.48

If we reject these — though the suggestion is somewhat disquieting — the corresponding equation of the above series becomes

$$18.91x - 0''.0520 = 0$$

The value of Δ Aberration $+ 0.1430$

Aberration 20.5881

Taking the mean between this and the first of the above we have

20″.581

which I regard as the legitimate result of this investigation. The probable error computed in the usual way would be something less than 0″.01, but this is of very little significance in view of the considerable systematic errors to which this, in common with all determinations of this constant seem to be liable.

Whatever value may ultimately be adopted, it will presumably not be so large as this. At the same time it is obvious that STRUVE's value is too small to properly harmonize the evening and morning observations of the present series.

The value 20″.55 has therefore been employed, the corresponding correction being applied to the latitude originally computed with STRUVE's value.

The final results are as follows:

Latitude = 39° 58′ +

Date	P.M.	No.	A.M.	No.	Mean	Date	P.M.	No.	A.M.	No.	Mean
1896 Oct. 1–Oct. 25	″ 1.915	63	″ 1.878	74	″ 1.896	1897 Oct. 4–Oct. 14	″ 2.258	61	″ 2.363	43	″ 2.310
Oct. 26–Nov. 9	1.906	59	1.928	50	1.917	Oct. 15–Nov. 4	2.110	53	2.093	39	2.101
Nov. 13–Nov. 27	1.811	80	1.921	62	1.866	Nov. 20–Dec. 10	2.102	75	2.186	44	2.144
Dec. 14–Jan. 11	. .	. .	2.063	108	2.063	Dec. 12–Dec. 30	. .	. .	2.025	84	2.025
1897 Jan. 23–Feb. 4	2.064	70	2.049	48	2.056	1898 Jan. 1–Jan. 24	. .	. .	2.038	73	2.038
Feb. 7–Feb. 25	2.030	52	2.039	52	2.034	Jan. 31–Feb. 8	1.985	55	2.009	52	1.997
Feb. 27–Mar. 14	2.102	76	2.204	58	2.153	Feb. 10–Feb. 28	2.153	79	2.095	42	2.124
Mar. 16–Apr. 20	. .	. .	2.223	100	2.223	Mar. 1–Mar. 14	1.938	58	2.137	53	2.037
May 7–May 21	2.224	62	2.283	63	2.253	May 9–May 30	2.197	74	2.210	51	2.203
May 22–June 2	2.254	67	2.290	76	2.272	May 31–June 10	2.149	71	2.273	64	2.211
June 18–July 4	. .	. .	2.274	87	2.274	June 21–July 2	. .	. .	2.215	88	2.215
July 5–July 24	2.194	80	2.304	54	2.249	July 3–July 16	2.287	68	2.322	68	2.304
July 29–Aug. 7	2.201	61	2.281	57	2.241	July 29–Aug. 16	2.277	83	2.394	44	2.336
Aug. 11–Aug. 26	2.320	79	2.241	63	2.280						
Sept. 8–Sept. 28	. .	. .	2.296	90	2.296						

Total number of determinations 3213.

The internal probable error of a single observed latitude as derived from the reduction of the individual latitudes to the mean of each group is found to be as follows:

For group	I	″ 0.133	For group III	″ 0.131
	II	0.139	IV	0.125

The Flower Observatory, Philadelphia, 1898 *Nov.* 28.

ADDITIONAL NOTE ON THE MASS OF *MERCURY*,

BY G. W. HILL.

Since the appearance of the Note on the Mass of *Mercury* (*A.J.* No. 452) it has occurred to me that the cause of the Moon giving a larger mass for *Mercury* than the three other bodies treated is the neglect of the augmentation of density through the loss of interior heat. The smaller the dimensions of the body considered, the greater will be this augmentation, provided other conditions remain the same. Now the Moon is the smallest of the four bodies treated in the previous note. In the lack of any information as to the original temperature and the length of time the cooling has been going on, it seems the best we can do is to suppose that the effect on the general density of the body is proportional to some power of the radius. This power can be determined from the data given in the previous note, by adopting the principle that that value is to be used which will bring the results from the four bodies into closest agreement. Thus, employing the method of least squares, we find that the exponent 3 of the ratio $\frac{a'}{a}$ used in the former note, ought to be reduced to 2.92849. This is not an excessive correction to make for the effect of cooling. Substituting the latter value of the exponent for the former, the values of the mass of *Mercury*, severally from the four bodies treated, are

Venus	*Earth*	*Moon*	*Mars*
$\frac{1}{10\,710\,000}$	$\frac{1}{10\,191\,200}$	$\frac{1}{10\,403\,600}$	$\frac{1}{10\,826\,200}$

These values are in much better agreement than the former, and the mean gives for the mass of *Mercury* $\frac{1}{10\,530\,300}$.

OBSERVATION OF LEONIDS, WITH NOTE UPON ONE OF PECULIAR INTEREST,

By J. B. COIT.

Instead of attempting to observe the Leonids at Boston University Observatory, in the heart of the city, I watched for them, assisted by my son, W. A. COIT, at my home in Melrose Highlands. We thus had the best possible sky, with scarcely any glare from electric lights.

Upon the mornings of Nov. 13 and 14 the sky was overcast, but on the 15th the air was exceedingly clear, temperature 33° and wind N.W., light.

Counts were made of Leonids only, for about two hours, beginning at 3 A.M. One observer faced the east and one the west.* The view was unobstructed. The largest number counted in any consecutive five minutes was 16. This was from $3^h\ 40^m$ to $3^h\ 45^m$ E.M.T. The smallest number was 8, at $3^h\ 20^m$. During the entire period the numbers seen east and west were nearly equal. Only three were estimated as of first magnitude, one as brighter.

At $4^h\ 13^m$ a meteor started from about $\alpha = 10^h$, $\delta = +30°$. It moved in four seconds to the point $\alpha = 10^h$, $\delta = +35°$. These points were determined, subsequently, upon a large star map. At the time of observation it was announced as of a "dazzling, purplish blue" and as two or three times as bright as *Sirius*, presenting a distinct disc. At the second point, named above, the combustion seemed to be completed. No trail remained, but the *débris*, appearing like a bright nebula, took at once the form of a sickle with a short blade; this being concave as viewed from the point whence the meteor started, and having a length of about 2° and a width of 10′. This mass, after remaining in the same form for a few seconds, began to change its form and expand rapidly. All this time it was moving apparently along in nearly the same direction as the line of flight. It was easily followed for seven minutes with the naked eye, and its presence was suspected nearly 2^m later. When lost to view it was near *β Ursae Majoris*. When largest it was nearly circular and estimated to be 5° in diameter.

This mass moved at least 20° during 7^m. Hence, even if its line of movement were perpendicular to the line of sight, a very moderate estimate of its distance would indicate a comparatively high velocity. That its movement was not perpendicular to the line of sight was rendered highly probable by the fact that the velocity of the mass was decidedly accelerated throughout the seven minutes that it was observed.

The slow motion of the meteor proved that its path made a very small angle with the line of sight, and, although it is not proved, the probability is strong that the *débris* moved along nearly the same line, and that its movement may not have been due entirely to atmospheric currents, but was influenced by the momentum of the body acquired during its flight as a meteor.

* The plan did not include a determination of the radiant point, but of the number whose apparent paths seemed to be directed from within the sickle, or immediately adjacent to it.

OCCULTATIONS OBSERVED AT PRINCETON DURING THE LUNAR ECLIPSE OF DECEMBER 27, 1898,

COMMUNICATED BY PROFESSOR YOUNG.

The weather during the eclipse was not favorable. The moon rose in a cloud-bank, and did not emerge until just before the beginning of totality. During totality it was partially covered nearly half the time by light mists and flying clouds, and often was entirely hidden; it was perfectly clear only a few minutes, about $7^h\ 10^m$ (Standard Time). Fifteen minutes later the sky became entirely overcast, and remained so for over two hours, when fortunately it cleared, so that Professor REED was able to obtain a satisfactory determination of the time. During the eclipse, stars of the 9th magnitude, or fainter, were most of the time invisible, or if visible, could be followed up to the limb of the moon only with very great difficulty.

Professor REED observed at the Halstead Observatory with the 25-inch telescope, using a power of 156. I myself observed at the Observatory of Instruction with a 9½-inch equatorial, and a power of about 120. The two observatories are electrically connected, and the same clock, — the sidereal clock of the Observatory of Instruction — furnishes the time to both the chronographs on which the observations were recorded. The clock-error was found to be $+7^s.32$, and has been applied to all the chronograph readings. The hourly rate was less than $0^s.02$, and has been neglected.

In the following table the numbers by which the stars are designated are those of the observation-list sent out by the Pulkowa Observatory. In deducing the G.M.T. from the observed sidereal times the data of the American Ephemeris are used; and in the case of those observations which are noted as "good," the indicated correction of $-0^s.2$ has been applied in order to take into account the reaction-time involved in the use of the observing-key.

The only physical peculiarity which I noticed during the eclipse was the persistent difference in brightness between the northern and southern limbs, the former being much the brighter.

No.	Mag.	I. or E.	Sidereal Time (corrected)	G.M.T.	Obs.	Remarks
78	9.4	Imm.	0 43 59.5 ±2	11 16 47.9	Y	Very faint
. .	. .	. .	. . 61.6 ±3	. . 50.0	R	Poor
75	7.4	Imm.	0 45 40.1 −0.2	11 18 28.0	Y	Satisfactory
. .	. .	. .	. . 40.2 −0.2	. . 28.1	R	Good
80	9.4	Imm.	0 54 04.3 ±2	11 26 51.1	Y	Very faint
. .	. .	. .	. . 00.1 ±3	. . 46.9	R	Poor
84	7.7	Imm.	1 24 13.3 −0.2	11 56 51.9	Y	Good
. .	. .	. .	. . 12.8 −0.2	. . 54.4	R	Good
92	9.3	. .	1 28 30.2 ±2	12 01 11.4	R	Poor
75	7.4	Emer.	1 35 13.3 ±0.5*	12 07 53.3*	Y	Good, but see note
94	9.1	Imm.	1 47 42.8 ±1	12 20 20.8	Y	Faint
. .	. .	. .	. . 41.3 −0.2	. . 19.2	R	Fair observation

* NOTE. — The star reappeared exactly at the point under observation, but about half a minute earlier than expected. I had laid down the observing key, and was obliged to reach for and find it. This caused a slight delay of about one magnet-beat (two seconds), which has been allowed for in the record; but the correction may be uncertain by half a second.

Princeton, N. J., 1898 *Dec.* 30.

NOTE ON A NEW LAW OF TEMPERATURE FOR GASEOUS CELESTIAL BODIES.

By T. J. J. SEE.

While occupied with some researches on the heat of the sun, and on the cause of the darkness of the companion of *Sirius*, in May, 1898, I proved that for every gaseous celestial body the law of temperature will be expressed by the following remarkable formula:

$$T = \frac{K}{R}$$

where T is the absolute temperature, R the radius, and K a constant, different for each body. The curve of temperature is thus a rectangular hyperbola referred to its asymptotes. This law, governing the development of stars from nebulas, is one of the utmost generality, and during the past eight months I have drawn from it some conclusions regarding the relative ages of the stars and nebulas, which will, I think, settle the much debated question of the proper classification of the stars of different spectral types. These conclusions, drawn from the above fundamental law of nature, were made known to several distinguished astronomers as much as six months ago, and were announced more fully in a public lecture at the Lowell Institute, Boston, Jan. 10, 1899.

Cambridge, Mass., 1899 *Jan.* 12.

OBSERVATIONS OF THE PLANET *DQ*.*

MADE AT THE WASHBURN OBSERVATORY, MADISON, WIS.

By GEORGE C. COMSTOCK.

The following observations of Planet *DQ* were all made with the filar micrometer of the 40-cm. Clark equatorial telescope of the Washburn Observatory, provided with an ocular magnifying 195 diameters. Wherever possible I have measured directly with the micrometer the polar coordinates of the planet referred to the comparison-star, and observations thus made are indicated by the letter *a* placed in the third column of the table. When the distance was too great to permit of this mode of observing, I have employed transits by eye and ear over the micrometer threads for the differences of right-ascension, and have measured only the differences of declination by means of the micrometer-screw. In the reduction of all of the observations the errors of the screw have been carefully taken into account. Where transits are observed, each comparison in right-ascension consists of an independent setting of the telescope and a transit of planet and star over four threads. Each comparison in declination consists of a separate setting of the telescope and a single pointing of the micrometer-thread upon each object. One-half of the comparisons in right-ascension precede and one-half follow the declination observations. The number of comparisons is such that the probable error of an average $I\alpha$ or $I\delta$ may be assumed to be $\pm 0''.25$ of a great circle.

* This planet has now received the name *Eros*. — ED.

1898 Madison M.T.	*	No. Comp.	Planet − * $\Delta\alpha$	Planet − * $\Delta\delta$	Planet's apparent α	Planet's apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			m s	′ ″	h m s	° ′ ″		
Sept. 24 9 1 43	1	*a*	+0 1.87	+1 3.4	20 36 5.65	−6 20 17.2	8.888	0.823
26 8 53 18	1	10 , 6	−0 19.41	+2 0.1	35 44.35	6 19 20.6	8.888	0.823
27 9 39 53	1	*a*	−0 25.84	+2 34.9	35 37.90	6 18 45.8	9.222	0.820
29 8 26 41	1	16 , 6	−0 28.69	+3 55.4	35 35.01	6 17 25.3	8.665	0.823
Oct. 4 8 19 27	1	*a*	+0 12.88	+8 47.8	36 16.50	6 12 32.9	8.571	0.823
11 8 52 43	2	10 , 5	+0 32.53	−4 35.2	39 9.27	6 1 45.3	9.249	0.818
14 8 18 42	2	10 , 6	+2 23.17	+1 33.0	40 59.84	5 55 37.2	9.129	0.818
28 7 26 20	3	9 , 6	−1 19.37	−5 39.4	53 55.90	5 12 48.0	9.062	0.815
31 7 13 40	4	5	+0 56.64	. . .	20 57 29.46	. . . .	9.031	. .
31 7 29 14	4	5	. . .	+3 14.6	. . . .	−5 0 23.5	. .	0.813
Nov. 2 6 52 15	5	*a*	−0 13.48	−5 19.6	21 0 1.15	4 51 36.0	8.888	0.813
3 7 51 10	5	12 , 6	+1 8.19	−0 58.5	1 22.81	4 46 44.9	9.274	0.810
6 7 3 38	6	*a*	−0 34.81	+0 53.7	5 24.40	4 32 8.9	9.065	0.810
10 7 50 52	7	10 , 6	−1 56.49	−4 12.8	11 14.15	4 10 23.7	9.333	0.805
11 6 31 52	7	13 , 6	−0 31.02	+1 14.1	12 39.61	4 4 56.8	8.904	0.807
15 7 7 29	8	11 , 6	+1 44.60	−6 57.2	18 56.58	3 40 28.2	9.210	0.804
Dec. 1 6 51 16	9	*a*	+0 14.39	+4 31.9	47 7.05	1 40 52.6	9.290	0.789
3 7 51 37	10	14 , 6	−0 55.03	−7 25.9	51 2.60	1 23 3.3	9.466	0.785
4 6 38 27	10	13 , 7	+0 55.94	+1 1.4	52 53.56	1 14 36.1	9.264	0.786
6 6 51 9	11	*a*	+0 6.76	−7 49.4	56 51.34	0 56 20.4	9.332	0.783
7 6 57 44	12	11 , 5	−1 45.04	+1 33.1	21 58 51.14	0 46 59.5	9.352	0.783
11 6 34 50	13	10 , 6	+0 51.62	−5 49.6	22 6 57.28	−0 8 30.3	9.301	0.777
25 6 25 14	14	*a*	−0 9.40	+0 8.0	37 14.80	+2 22 40.9	9.352	0.760
31 6 34 52	15	12 , 6	+0 34.05	−1 58.2	51 4.47	+3 34 35.0	9.406	0.752

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 35 59.62	+4.16	−6 21 38.3	+17.7	$\frac{1}{4}$(Radcliffe III + Karlsruhe II
1		+4.14		+17.6	+ Karlsruhe IV + A.G.Z. Ottakring)
1		+4.12		+17.6	
1		+4.08		+17.6	
1		+4.00		+17.6	
2	20 38 32.82	+3.92	−5 57 27.9	+17.8	$\frac{1}{5}$(2 Karls. II + 2 Karls IV + A.G.Z. Ottakring)
2		+3.85		+17.7	
3	20 55 11.55	+3.72	−5 7 27.5	+18.9	$\frac{1}{4}$(Radcliffe III + 3 Cape, 1885) 11 *Aquarii*
4	20 56 29.14	+3.68	−5 3 57.2	+19.1	Karlsruhe V
5	21 0 10.96	+3.67	−4 46 5.8	+19.4	$\frac{1}{3}$(Radcliffe III + Karls. II + Karls. IV)
5		+3.66		+19.4	
6	21 5 55.56	+3.65	−4 33 22.4	+19.8	$\frac{1}{2}$(Karlsruhe II + Karlsruhe IV)
7	21 13 7.04	+3.60	−4 6 31.0	+20.1	Karlsruhe V
7		+3.59		+20.1	
8	21 17 8.43	+3.55	−3 33 51.5	+20.5	$\frac{1}{3}$(Arg.Gen.Catal. + Radcliffe III + Karls. II)
9	21 46 49.16	+3.50	−1 45 46.8	+22.3	$\frac{1}{2}$(Munich I + Copeland and Börgen)
10	21 51 54.13	+3.50	−1 16 0.1	+22.7	$\frac{1}{6}$(2 Mun.I + C. and Börg. + B.B.VI + *A.N.* 1244)
10		+3.49		+22.6	
11	21 56 41.11	+3.47	−0 48 53.8	+22.8	$\frac{1}{3}$(2 Romberg + Copeland and Börgen)
12	22 0 32.69	+3.49	−0 48 55.6	+23.0	*B.J.* + *Ast. Nach.* 3509. *a Aquarii*
13	22 6 2.21	+3.45	−0 3 4.0	+23.3	$\frac{1}{4}$(B.B. VI + Schj. + Cope. and B. + *A.N.* 1712)
14	22 37 20.72	+3.48	+2 22 8.2	+24.7	$\frac{1}{6}$(Munich I + 2 *A.N.* 1328 + 3 A.G.Z., Albany)
15	22 50 26.91	+3.51	+3 36 7.8	+25.4	A.G.Z., Albany

a Both coordinates measured with micrometer.

Oct. 28. Comparison through a star $9^{M}.5$ disk 45″ from planet. Planet very faint and observation difficult on account of haze and moonlight.

Oct. 31. Incomplete observation through gathering clouds. The declination is especially poor.

Nov. 3. Planet faint and difficult, through gathering clouds.

Dec. 1. The catalogue star-places are reduced to the A.G. system by means of the systematic corrections given in Munich I.

Dec. 3. Planet very faint and difficult.

Dec. 25. Strong moonlight. Planet faint but observations are good.

PROVISIONAL RESULTS OF LATITUDE-MEASUREMENTS AT THE ROYAL OBSERVATORY AT PRAGUE, 1897 OCTOBER 1 TO 1898 DECEMBER 1 (*HORREBOW-TALCOTT*),

COMMUNICATED BY L. WEINEK.

Date	Obs.	φ	Pairs	Date	Obs.	φ	Pairs	Date	Obs.	φ	Pairs
1897 Oct. 1	L	50° 5′ 15″.84	9	1898 June 6	O	50° 5′ 15″.34	4	1898 Aug. 27	O	50° 5′ 15″.63	3
2	S	15.93	9	9	O	15.75	7	29	O	15.92	9
16	S	16.29	9	10	O	15.59	17	Sept. 2	S	15.80	1
24	S	16.31	17	11	L	15.57	8	2	O	16.20	9
25	W	16.18	9	12	O	15.60	3	6	S	15.99	9
Nov. 11	L	15.67	9	13	S	15.87	8	6	O	15.86	8
14	S	16.33	9	13	O	15.55	9	8	S	16.18	9
Dec. 28	S	16.12	8	18	S	15.54	8	8	O	16.17	8
29	W	16.08	7	18	O	15.32	2	9	S	16.10	8
1898 Jan. 1	S	15.94	8	21	S	15.93	7	11	O	15.95	9
Feb. 3	S	16.11	1	21	O	15.56	13	15	O	16.19	5
6	S	16.30	4	July 3	S	16.04	13	16	S	15.93	9
19	W	15.81	6	6	O	15.84	13	16	O	15.86	8
21	W	15.71	9	16	O	15.52	13	17	S	16.05	9
24	W	15.47	8	18	O	15.65	14	18	O	16.05	9
27	L	15.53	10	21	O	15.74	15	19	O	15.87	9
Mar. 13	L	16.03	13	25	O	15.51	2	26	S	15.95	3
14	S	16.31	2	26	O	15.80	9	26	O	16.03	9
21	S	15.75	10	31	O	15.89	10	27	S	16.44	5
28	S	15.76	8	Aug. 2	O	16.03	17	Oct. 3	O	16.04	8
31	S	15.60	7	6	O	15.86	10	4	S	15.92	5
Apr. 6	S	15.95	8	12	O	15.97	9	5	S	15.33	1
6	O	16.06	2	13	S	15.88	9	9	O	15.97	9
12	S	16.05	5	13	O	15.81	8	10	O	16.04	9
12	O	15.41	7	14	S	16.21	8	26	O	15.94	8
16	O	15.54	7	11	O	15.96	8	27	O	16.24	9
19	S	16.19	8	16	O	15.89	8	Nov. 3	O	16.22	4
19	O	15.94	7	17	S	15.96	8	6	S	16.53	1
May 1	S	15.93	14	17	O	15.86	9	6	O	15.96	9
2	L	15.44	9	19	S	16.29	8	8	S	16.12	9
14	S	15.89	10	19	O	16.09	9	17	O	15.94	9
22	O	15.89	6	21	O	15.68	8	18	S	16.10	9
24	O	15.55	10	22	S	16.09	8	18	O	15.91	8
June 4	S	15.43	8	22	O	15.85	9	19	S	50 5 16.07	9
4	O	50 5 15.55	8	26	S	50 5 16.31	4				

OBSERVERS. — W = Prof. Dr. L. WEINEK. S = Dr. R. SPITALER. O = Dr. E. v. OPPOLZER. L = R. LIEBLEIN

MONTHLY MEANS, WEIGHTED ACCORDING TO NUMBER OF PAIRS.

Mean Date	Mean φ	Pairs	Interval	Mean Date	Mean φ	Pairs	Interval
1897 Oct. 15.2	50° 5′ 16″.14	53	Oct. 1–25	1898 June 12.4	50° 5′ 15″.60	102	June 4–21
Nov. 12.5	16.00	18	Nov. 11–14	July 17.8	15.77	89	July 3–31
Dec. 29.3	16.04	23	Dec. 28–Jan. 1	Aug. 15.6	15.96	152	Aug. 2–29
1898 Feb. 20.8	15.70	38	Feb. 3–27	Sept. 13.5	16.04	127	Sept. 2–27
Mar. 21.2	15.84	40	Mar. 13–31	Oct. 13.7	16.02	49	Oct. 3–27
Apr. 13.7	15.86	44	Apr. 6–19	Nov. 13.3	16.04	58	Nov. 3–19
May 11.2	15.75	49	May 1–24				

Prag, K. K. Sternwarte, 1898 *Dec.* 13.

ELEMENTS AND EPHEMERIS OF COMET *j* 1898 (CHASE),

BY E. F. CODDINGTON.

From my observations of Nov. 23, Dec. 7 and Dec. 16, I have computed the following elements of this comet. From the same observations I also computed two other systems of elements, and from a comparison of the residuals furnished by the three it was evident that, while the residuals here given may be slightly reduced, the elements themselves will not be materially changed. The magnitude of the residuals may result from errors of observation, since the comet was a rather difficult object for the 12-inch telescope, which was used in making the first two observations.

ELEMENTS.

$$T = 1898 \text{ Sept. } 20.15344$$

$$\left.\begin{aligned} \omega &= 4^\circ\ 37'\ 59''.9 \\ \Omega &= 95\ 51\ 35.9 \\ i &= 22\ 30\ 20.3 \end{aligned}\right\} 1899.0$$

$$\log q = 0.358892$$

$$\text{O}-\text{C}, \quad \Delta\lambda' \cos\beta' = +5''.3 \quad , \quad \Delta\beta' = -3''.2.$$

Mt. Hamilton, 1898 *Dec.* 24.

EQUATORIAL COORDINATES, 1899.0.

$$x = r[9.965987] \sin(190^\circ\ 58'\ 21''.2 + v)$$
$$y = r[9.971669] \sin(109\ 28\ \ 4.4 + v)$$
$$z = r[9.703552] \sin(\ 56\ 14\ 56.6 + v)$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1899	α h m s	δ ° ′ ″	log Δ	Br.
Jan. 1.5	11 4 32.80	+28 41 33.6	0.2763	1.15
3.5	5 42.88	29 3 12.7	0.2746	
5.5	6 46.01	29 25 16.7	0.2730	1.15
7.5	7 42.28	29 47 42.6	0.2715	
9.5	8 31.49	30 10 26.2	0.2703	1.14
11.5	9 13.76	30 33 25.2	0.2691	
13.5	9 48.91	30 56 34.5	0.2682	1.14
15.5	10 17.04	31 19 51.9	0.2674	
17.5	10 38.29	31 43 12.4	0.2668	1.13
19.5	10 52.71	32 6 30.4	0.2664	
21.5	11 0.44	32 29 43.4	0.2662	1.11
23.5	11 1.59	32 52 46.3	0.2662	
25.5	10 56.31	33 15 34.9	0.2664	1.09
27.5	10 44.83	33 38 5.0	0.2668	
29.5	11 10 27.28	+34 0 10.6	0.2674	1.06

OBSERVATION OF COMET *j* 1898,

MADE WITH THE 36-INCH REFRACTOR OF THE LICK OBSERVATORY,

BY R. G. AITKEN.

Mt. Hamilton M.T.	⁎	No. Comp.	☄ − ⁎ Δα	☄ − ⁎ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
1898 Dec. 2 14h 38m 54s	1	8 , 8	+10s.41	−1′ 27″.2	10h 34m 28s.88	+24° 26′ 31″.5	*n*9.568	0.455

Mean Places for 1898.0 of Comparison-Stars.

⁎	α	Red. to app. place	δ	Red. to app. place	Authority
1	10h 34m 14s.22	+4s.25	+24° 28′ 27″.5	−28″.8	Micrometer-comparison with ⁎2
2	10 35 46.68	+4.24	+24 29 37.4	−28.9	Becker, Berlin A.G. Catal. 4078

Δα was measured micrometrically. The comet is small, with well-marked condensation, but no stellar nucleus. In brightness it was estimated as equal to a 12th magnitude star. It was well seen in spite of moonlight and considerable haze.

Lick Observatory, University of California, 1898 *Dec.* 23.

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DISCORDANCES BETWEEN THE NORTH POLAR DISTANCES OF STARS DERIVED FROM DIRECT AND FROM REFLECTION OBSERVATIONS.

By J. R. EASTMAN.

It is many years since POND, the Astronomer Royal at Greenwich, mounted two Mural Circles side by side and determined, by simultaneous direct observations of the same star, the systematic differences between the results from the two circles. He then observed the same star *directly* with one circle and by reflection with the other, and was pained to find that the results did not agree. Moreover, he found that the differences between the direct and reflection results, $D-R$, presented one set of more or less consistent values for stars *north* of the zenith, and a different set of values from stars *south* of the zenith.

This puzzle has confronted every observer with a Meridian Circle who has tried to use reflection observations, from the time of POND's experiments to the closing years of the nineteenth century, and has probably caused a wider feeling of discomfiture among astronomers than any other problem in practical astronomy.

I know of no exception to the general rule that, in the work of every circle that has employed reflection observations in the determinations of absolute declinations or north polar distances, the results from direct and reflection observations do not agree, and that the difference between such results for stars *north* of the zenith is not the same as for stars *south* of the zenith.

If we attempt an examination of this perplexing question, we naturally turn first to the records of the Greenwich Observatory, where the continuous work in this direction, in accordance with an undeviating plan, stands unrivalled in the history of practical astronomy.

Unfortunately POND left no complete discussion of his results, and we are forced to content ourselves with his verbal accounts of the difficulties which he encountered, and even these rare expressions are to be gleaned only from the papers of his younger contemporaries.

The first important discussion of English observations appears in a paper [1] on the Latitude of the Cambridge Observatory by G. B. AIRY, afterwards Sir G. B. AIRY and Astronomer Royal at Greenwich.

Regarding the various values of $R-D$, AIRY wrote, "In vain have I endeavored to discover the cause of this discordance." Again, "I am driven at last to the supposition that the circle changes its figure; but I know no proof of this, nor do I see distinctly how it should produce the discordance in question."

AIRY soon became the Director of the Greenwich Observatory and carried on the reflection observations and reductions according to the same plan which he had adopted at Cambridge. In 1851 the new Transit-Circle was mounted, and, with this new instrument, which combined the improvements suggested by the skill of the artisan and the experience of the astronomer, AIRY found the same discordances which had proved so annoying in the work of the more primitive Mural Circles. He then began anew his studies of these discrepancies but never arrived at any satisfactory conclusion.

In the Greenwich volume for 1851 appears the following list of values of $R-D$, collated into groups, each covering several degrees of north polar distance, both *north* and *south* of the zenith:

$R-D$

North of the Zenith	South of the Zenith
″	″
+0.60	+0.11
+0.71	−0.08
−0.08	+0.11
+0.29	−0.18
+0.31	−0.06
+0.15	

In the volume for 1852 are given the following values

(1) *Cambridge Philosophical Transactions*, Vol. V, 271.

of $R-D$ derived from the observations of 1852 and arranged in the same order as those from the previous year:

North of the Zenith	South of the Zenith
$+0''.45$	$+0''.62$
-0.02	$+0.06$
-0.61	-0.17
$+1.08$	-0.96
$+0.41$	-0.29
	$+0.10$
	-0.10

Of the values of $R-D$ for 1852 the Astronomer Royal wrote, "The want of continuity in the above values of $R-D$ render it useless to attempt to combine them according to any function of the zenith distance; yet as there is manifestly a correction due on the whole, which would be moderately well represented by that deduced from the observations of 1851, and as it is not likely on other grounds that the mechanical circumstances on which the corrections depend are essentially different, it is thought best to apply the same corrections as in the preceding year."

In the volume for 1857 Airy wrote in regard to the system of corrections derived from the $R-D$ results, "Although these tabulated numbers have been used in the final reductions of the results it cannot be said that their introduction is quite satisfactory."

In the volume for 1859 he wrote, "In the reductions for the year 1859 (which is intended to close a period of groupings for the formation of a new catalogue), I have been unwilling to depart from a system of corrections for $R-D$ which has been followed for many years. Yet I cannot disguise my feeling that it is very improbable that this correction ought to be applied to the direct results."

In the introduction to the seven-year catalogue for the epoch 1860, Airy wrote, on page ix, "The comparison of these results seems to render it extremely probable that the origin of the discordance expressed by $R-D$ lies in some conformation of the warmer and cooler strata of the atmosphere in the immediate neighborhood of the circle."

In a paper read before the Royal Astronomical Society on May 8, 1863, (1) the Astronomer Royal discussed more fully than before the discordance of direct and reflection observations. From this paper I make the following quotations: "From that time (1834) to the present, I have always used the same principle of adopting the mean between the result of direct observation and the result of reflection observation." Again, "It appears from this that the correction $\frac{1}{2}$ $(R-D)$ or $\frac{3}{5}$ $(R-D)$ is a real correction founded on some physical cause. Upon this I would first remark that I do not conceive that there is any room for explanation from defects of the instruments." Finally, "It appears probable that no co-latitude of an observatory, where direct observations alone are used, is certain to a quarter of a second, and no north polar distance of stars at 70° or 80° from the pole is certain to half a second. I know no method of removing this doubt but the introduction of reflection observations of stars on both sides of the zenith."

(1) Mem. Royal Astronomical Society, XXXII, 9

In each Greenwich volume, from 1860 to 1880, is found the following allusion to the $R-D$ results: "The general system of corrections for $R-D$ which has been followed for many years has been retained in the present volume. A careful examination of the different values obtained in different years has convinced me that the quantity is real, but I am still unable to explain perfectly its origin."

I have quoted thus freely from the remarks and conclusions of the late Astronomer Royal at Greenwich for the purpose of calling attention to several conclusions, derived from the discussion of many $R-D$ results, that have generally guided English astronomers and appear to have influenced the work of the majority of other astronomers since the introduction of the divided circle as an instrument of precision.

The principal conclusions reached in the discussions from which the above quotations are taken, and some of which I propose to consider briefly, are:

1°. Direct and reflection observations are entitled to equal weight.

2°. The correction $\frac{1}{2}$ $(R-D)$ or $\frac{3}{5}$ $(R-D)$ is a real correction to the observed north polar distance and is founded on some physical cause.

3°. The correction is continuous from the northern limit of observation, through the zenith, to the southern limit of observation, and is a function of the zenith distance.

4°. It is generally admitted, if not asserted, that all the instrumental defects of the circles and telescope, like errors of division, flexure of telescope and circle, etc., were thoroughly known, and that it was not likely that any such causes could produce the troublesome discrepancies that have so long vexed astronomers.

Most, if not all, of the above four statements have had great weight in determining the attitude of modern astronomers towards this subject, chiefly because of the justifiable respect for the integrity and ability of Sir George B. Airy; but I feel quite certain that the dictum embodied in the last of the four points enumerated is largely responsible for discouraging investigation in a field that, apparently, is not yet exhausted.

These four statements, which have gradually grown to have the weight of well established authority, seem to me

to be fruitful subjects for discussion, containing many questions that are yet far from final settlement.

At present I wish to consider some of the questions involved in the fourth proposition, which assumes that the errors of the instruments are all known and that the causes of the discordances must be sought for elsewhere.

If we examine the history of the telescope as well as the structure of the modern instrument, it will be seen readily that it was designed for use on objects above the horizon. If the objective in its cell be carefully fitted into the collar on the end of the telescope tube, in the usual way, it is probable that, for work on all objects observed *directly*, the objective would, simply by the action of gravity, maintain its position with relation to the telescope tube. But when the telescope is pointed below the horizon for observing the nadir or a reflected star, all the conditions are immediately changed. The weight of the objective, or the weight of the objective and cell combined, produces an unusual strain on the screws which hold the objective in its cell and the cell in the collar. If the objective in its cell, the cell in the collar or the collar on the telescope be free to move in the least degree in such a manner as to *tilt* the objective in the direction of the meridian, then the observed reflected image of a star will be displaced more or less in zenith distance. Such a tilting of the objective would produce similar errors in both nadir and reflection observations.

Differences in results from reflection observations north and south of the zenith might also arise from motion in the sliding tube which carries the eye-piece, or from motion of the plate carrying the fixed threads of the eye-piece.

The latter contingency in the case of the Washington transit circle is highly improbable. The sliding tube of that instrument with the eye-piece and attachments weighed about fourteen pounds. This tube was held in place by means of a screw working through the collar at the end of the telescope-tube and against a slightly curved steel bar lying against the tube and parallel to its axis. This bar was about 5 inches long, 0.75 inch wide and 0.25 inch thick. A steel spring of the same length as the bar, but with greater curvature, rested in a slot 0.5 inch wide and 0.12 inch deep on the under side of the bar. When the sliding tube was in position with the fixed threads of the eye-piece in the stellar focus of the objective, the spring and bar were forced by the screw against the sliding tube to hold it in place.

The action of the screw was in the plane of the meridian, and the sliding tube was supported on two bearings 0.75 inch wide and 120° from the spring and from each other. When the clamp was *east* and the telescope was pointed to the *south* the weight of the tube and eye-piece and the pressure of the spring acted in the *same* direction; when the telescope was pointed to the *north* the weight and the spring acted in opposite directions.

As it was practically impossible to regulate the pressure exerted by the screw every time the tube was removed and readjusted, it is almost certain that this pressure varied within comparatively wide limits, and it is highly probable that the alternate combined and opposing action of gravity and the spring would produce opposite effects in the results from reflection observations *north* and *south* of the zenith.

When the telescope was pointed below the horizon most of the conditions under which the direct observations were made were reversed, and in the case of the reflected observations the tendency of the eye-piece was to move *toward* the objective. Such action with regard to the sliding tube would tend to produce such results as are found in table A in the *second*, *third* and *fifth* columns. Motion in the sliding tube would have little or no influence in the nadir observations.

The proper reductions of the reflection observations from which the values of ΔZ_n and ΔZ_s are derived require an accurate knowledge of the flexure of the telescope. The usually accepted method of finding the flexure of the telescope is to carefully level one collimator and then accurately point the second collimator on the first. When this adjustment is completed and maintained by frequent comparisons, the angle between the collimators is measured with the telescope, through the zenith or nadir.

The difference between this measured angle and 180° is adopted as the entire amount of the flexure. If we represent the whole amount of the flexure by f; the amount between the north collimator and the zenith by a; that between the south collimator and the zenith by b, then $a + b = f$. In practice it is generally accepted that $a = b = \frac{1}{2}f$. This is an assumption without even a fair amount of probability for a basis.

When the telescope is pointed to the north collimator one side of the telescope tube and cube is uppermost, and when the telescope points to the *south* collimator the other side of the tube and cube is uppermost.

It is possible but hardly probable that the flexure of the telescope is the same in the two positions. It may be true that this assumption has been the only available one in regard to the flexure, but it should not be employed to complicate other investigations whose results are essential to the accurate determination of the positions of stars. The problem in hand admits of no easy solution. If it were possible to determine the exact position of the nadir point then the measured angles from north collimator to nadir and from nadir to south collimator would furnish the data for finding the separate values of a and b. But while there is a possibility of a tilting motion of the objective, however small, the true nadir point cannot be fixed with certainty by nadir observations in one position of the instrument.

If the vertical collimator can be made to work with ease and accuracy, then the *zenith-point* can be found with the telescopic objective in its normal position and without any reference to the nadir point.

Until some method is found for determining separately the values of a and b the assumption that these quantities are equal will continue to be responsible, probably, for a large share of the numerical values of $\Delta Z_n - \Delta Z_s$ in table A, and the true systematic correction must be found by a symmetrical combination of the direct and reflection results.

From these causes, namely: tilting of the objective, unequal stress on opposite sides of the sliding tube, and erroneous assumption in regard to equality of flexure on both sides of the zenith; there have probably arisen three sets of errors, symmetrical with respect to the zenith, which have been introduced with greater or less magnitude into all the reductions of both direct and reflection observations wherever reflection observations have been employed to determine fundamental places.

The relative magnitudes of these different errors are probably in the inverse order in which the sources of the errors are named above.

At the Naval Observatory in Washington the cause of the discordances between the results from *direct* and *reflection* observations made with the Transit Circle was originally ascribed to some unknown error inherent in the method of determining the zenith-point correction, and the systematic corrections which were applied to the results and printed in the annual volumes from 1866 to 1888, were determined in accordance with that theory, by the methods explained in each volume.

These methods were founded on the assumption that the quantity $\Delta Z_n = \frac{D_n - R_n}{2}$ derived from observations of stars *north* of the zenith, and used with the sign changed, was the proper constant systematic correction to the observed north polar distances, direct and reflected, of all objects north of the zenith; and that a similar quantity, $\Delta Z_s = \frac{D_s - R_s}{2}$, derived from southern stars was the proper constant systematic correction to be applied, with the sign changed, to the results from all observations *south* of the zenith.

This method of determining the correction for discordances introduced an abrupt and perplexing change in its value at the zenith, sometimes reaching an embarrassing magnitude. The final results of using such systematic corrections for twenty-two years will be shown later.

In my own investigations of the work of the Transit Circle frequent comparisons of annual results in north polar distance gave no definite evidence of any variation in the values of $D-R$, on either side of the zenith, which depended on the zenith distance. If the objective were simply tilted by the action of gravity, no variation would be expected for zenith distances beyond 90°, and the nadir as well as the reflection results from stars would show the maximum effect of displacement.

Assuming such a displacement of the objective, the determination of the systematic error of the zenith-point correction depending on this displacement, however small it may be, may be considered as follows. If D represents the resulting north-polar distance of a star from *direct* observations, and R the resulting north-polar distance from reflection observations; then $\frac{D_n - R_n}{2} = \Delta Z_n =$ the error in the zenith-point correction as found from stars *north* of the zenith; while $\frac{D_s - R_s}{2} = \Delta Z_s =$ the error in the zenith-point correction as found from stars *south* of the zenith.

These should be really two determinations of the same quantity, and, if the other errors were known and eliminated, would be practically the same. But these two quantities ΔZ_n and ΔZ_s may and probably do contain errors due to imperfect knowledge of flexure, etc., which are of much greater magnitude than the one due to an insecure objective which has just been considered. Since there seems to be no good reason why a change in the position of the objective should have any effect on the results from *direct* observations, save through the effect of an erroneous zenith-point correction, the true annual systematic correction to the results from *direct* observations on account of error in the adopted zenith-point corrections would be $-\frac{(\Delta Z_n + \Delta Z_s)}{2}$.

For reflection observations the systematic correction would be the correction on account of error in the zenith-point correction *plus* the measured difference between the results from the direct and reflection observations *north* of the zenith, or $-\left[\frac{(\Delta Z_n + \Delta Z_s)}{2} + (D_n - R_n)\right]$.

For reflection observations *south* of the zenith the systematic correction would be $-\left[\frac{(\Delta Z_n + \Delta Z_s)}{2} + (D_s - R_s)\right]$.

The corrections for the effect of shifting the position of the sliding tube and for the use of erroneous flexure constants would also be symmetrically disposed about the zenith-point. According to the above interpretation of the discordance between the results from *direct* and *reflection* results, and from the method of deriving the systematic corrections, the annual values of ΔZ, to be applied to the results from *direct* observations, suffer no change at the zenith.

It was unfortunate that, before the final discussion of the results from the direct and reflection observations with the Washington Transit Circle was begun, the instrument was dismounted and such changes made in the length of

the telescope tube and in the mounting of the objective that it was impossible to make such measures as would lead to the definite determination of the motion of the objective and of the sliding tube or of the constants of flexure of the telescope in the two positions of that instrument.

It became necessary, therefore, to find some method of correcting the annual results already obtained with the Transit Circle in accordance with the system of reduction employed from 1866 to 1888.

With this end in view the following table, A, was constructed. This table exhibits the annual values of ΔZ_n and ΔZ_s as finally computed for the systematic corrections to the annual results derived from the work of the Transit Circle at the Naval Observatory. These are the values printed in the annual volumes, but since modified somewhat on account of errors found in the records and reductions. The *fourth* column contains the means of the quantities in the *second* and *third* columns or the finally adopted annual values of ΔZ. The *fifth* column contains the differences between the quantities in the *second* and *third* columns.

Table A.

Year	ΔZ_n	ΔZ_s	$\frac{\Delta Z_n+\Delta Z_s}{2}$ ΔZ	$\Delta Z_n-\Delta Z_s$	Year	ΔZ_n	ΔZ_s	$\frac{\Delta Z_n+\Delta Z_s}{2}$ ΔZ	$\Delta Z_n-\Delta Z_s$
	″	″	″	″		″	″	″	″
1866	+1.041	+0.371	+0.71	+0.67	1878	−0.374	−0.943	−0.66	+0.57
1867	+0.647	−0.099	+0.27	0.75	1879	+1.867	+0.997	+1.43	0.87
1868	+0.582	−0.135	+0.22	0.72	1880	−1.320	−2.570	−1.94	1.25
1869	+0.006	−0.578	−0.29	0.58	1881	+1.046	+0.463	+0.76	0.58
1870	+0.229	+0.220	+0.22	0.01	1882	−0.642	−1.292	−0.97	0.65
1871–2	+0.626	−0.439	+0.09	1.07	1883	+1.062	+0.579	+0.82	0.48
1873	+1.299	+0.576	+0.94	0.72	1884	−0.100	−1.101	−0.60	1.00
1874	−0.073	−0.664	−0.37	0.59	1885	+1.128	+0.341	+0.73	0.79
1875	+1.199	+0.423	+0.81	0.78	1886	−0.155	−1.003	−0.58	0.85
1876	+0.346	−0.600	−0.13	0.95	1887–8	+0.149	−0.685	−0.27	+0.83
1877	+0.988	+0.273	+0.63	+0.72					

An examination of the above table shows that all the values of $\Delta Z_n - \Delta Z_s$ have the same sign, also that, with the exception of those for 1870 and 1880, they are fairly accordant. In 1870 the Transit Circle was mounted anew in the new observing room and was used only the first six months of the year. The large values in 1880 are still unexplained. The mean of the annual values of $\Delta Z_n - \Delta Z_s$ is $+0''.73 \pm 0''.04$. An inspection of these values leads to the conclusion that they are the result of some peculiarity of construction or of adjustment in certain parts of the instrument, or of some error in the determination or in the use of the constants of flexure; and that in effect these errors are distributed symmetrically with regard to the zenith-point.

As a result of this investigation I have adopted the mean of the two determinations of ΔZ, *north* and *south* of the zenith, as the true systematic correction, or $\Delta Z = \frac{\Delta Z_n + \Delta Z_s}{2}$ as given in the *fourth* column of table A.

It now remains to compare the results obtained by the *old* methods of reduction with those derived in the manner which I have outlined and which for brevity I will call the *new* method.

The results of the work, on stars, with the Transit Circle of the Naval Observatory, have been embodied in the "Second Washington Star Catalogue" recently issued from the Government Printing Office.

That work was first reduced with the systematic corrections computed by the methods employed at the Naval Observatory from 1866 to 1888. Afterwards it was believed that good reasons existed for using the new method, and therefore the systematic corrections were all changed in accordance with the principles set forth in this paper.

Professor Newcomb, the ex-director of the American Ephemeris and Nautical Almanac, has been engaged, for some time, in preparing a standard catalogue of stars, entitled, "Catalogue of Fundamental Stars, for the epochs 1875.0 and 1900.0, reduced to an absolute system." The data on which this catalogue depends is, of course, derived from the best known sources, and the author has spared neither care, skill nor labor in making it what the title would indicate.

The data from the work of the Transit Circle, used by Professor Newcomb in the formation of his catalogue, were the results, in manuscript, derived from the observations by means of the *old* method of treating the reflection observations and computing the systematic corrections. For those places he derived a set of corrections to reduce them to his Fundamental Absolute System.

Comparison of Catalogues.

In the following table, B, I have given first the system of corrections which were found necessary to reduce the

positions derived from the Transit Circle work, by the *old* method of obtaining systematic corrections, to NEWCOMB's absolute system; second, the actual corrections by groups which were found by comparing the *first* reductions for the Washington Catalogue with NEWCOMB's list, star by star; and third, the differences between the *final* places of the Washington Catalogue, reduced by the new method, and NEWCOMB's absolute places.

In this table $Wn_2(1)$ denotes the places from the Washington Catalogue from the first reduction; Wn_2 denotes the final places from the Washington Catalogue obtained by the *new* reduction; and A.E. denotes the places from the American Ephemeris or from NEWCOMB's absolute system.

There is also included in this table a comparison of the results in Wn_2 with those in AUWERS's "Catalog der Fundamental-Sterne für die Zonen-Beobachtungen der Astronomischen Gesellschaft am Nördlichen Himmel; 1875.0;" and with the places in the "Catalogue of 500 Stars for the Epoch 1875.0" by Boss.

The subscript figures in columns four, five and six indicate the number of stars used in the comparison.

TABLE B.

Limits in N.P.D. of Groups Compared	Newcomb's Systematic Corrections to Wn_2 (I)	$Wn_2(1)$–A.E.	Wn_2–A.E.	Wn_2–Auwers	Wn_2–Boss
° °	″	″	″	″	″
0 to 10	−0.04	+0.04	$+0.04_8$	$+0.04_6$	-0.08_8
10 " 20	.11	.11	$.13_{24}$	$.12_{12}$	$+ .02_{24}$
20 " 30	.15	.16	$.18_{19}$	$.04_{11}$	$+ .06_{19}$
30 " 40	.19	.39	$.41_6$	$+ .16_6$	$+ .09_6$
40 " 50	.22	.27	$.25_9$	$.00_{10}$	$- .06_9$
50 " 60	.63	.63	$+ .01_{10}$	$- .27_8$	$- .17_{10}$
60 " 70	.68	.68	$- .12_{19}$	$.33_{15}$	$- .29_{19}$
70 " 80	.73	.72	$- .03_{21}$	$.37_{17}$	$- .12_{21}$
80 " 90	.77	.77	$- .01_{25}$	$.37_{19}$	$- .26_{24}$
90 " 100	.79	.77	$+ .02_{19}$	$.38_{12}$	$- .19_{19}$
100 " 110	.79	.80	$+ .03_{13}$	$.75_{18}$	$- .32_{12}$
110 " 120	.79	0.76	$+ .02_9$	-0.96_{14}	$- .23_9$
120 " 125	−0.80	+1.09	$+0.28_3$		-0.09_3

It will be noticed that the corrections in columns *three* and *four* for the *fourth* group in the above table, are especially large. The whole number of stars in that group is only six and the magnitude of the correction is chiefly due to the large residuals from *θ Ursae Majoris* and *θ Bootis.*

It will be seen also that the corrections for stars north of the zenith in columns three and four are practically the same. This arises from the fact that the value of ΔZ, as derived from the observations, is entirely independent of the assumed latitude while the correction, $\Delta\varphi$, to the assumed latitude depends on the adopted value of ΔZ. With the values of ΔZ derived from the *old* method of reduction the mean value of $\Delta\varphi$ from 21 years' observations was $-0''.50 \pm 0''.066$; with the *new* method the mean value of $\Delta\varphi$ was $-0''.10 \pm 0''.050$.

Andover, N.H., 1898 *Dec.* 1.

COMET *c* 1898 (CODDINGTON),

BY C. J. MERFIELD.

As it may be possible for northern observatories, having large telescopes, to obtain further observations of this apparition, the appended ephemeris has been computed from my elements as published in *A.N.* 3524.

That these elements may be referred to the mean equinox of the year 1899, the following reductions have been applied:

$$\Delta\omega = +0''.5 \qquad \Delta\Omega = +50''.1 \qquad \Delta i = +0''.1$$

The corrections to the ephemeris computed from the same elements, and extending from 1898 June to 1898 December, are represented thus:

$$d\alpha = +0^s.751 + [7.8563]t - [6.2326]t^2$$

$$d\delta = -0''.31 + [9.2594]t + [7.4749]t^2$$

in which $t = T - 220$; T being the day of the year 1898. On the date 1899 Jan. 15, the correction to the appended ephemeris may amount to -2^s in α, and $+1'\,43''$ in δ.

EPHEMERIS FOR GREENWICH MEAN NOON.

1899	α Apparent	δ Apparent	log Δ	1899	α Apparent	δ Apparent	log Δ
	h m s	° ′ ″			h m s	° ′ ″	
Jan. 15	1 41 50	−50 29 8		Feb. 14	2 23 11	−33 36 25	0.4530
17	1 44 53	−49 14 19	0.3858	16	2 25 44	−32 38 2	
19	1 47 52	−48 0 24		18	2 28 16	−31 40 50	0.4630
21	1 50 48	−46 47 26	0.3948	20	2 30 47	−30 44 50	
23	1 53 41	−45 35 27		22	2 33 17	−29 50 0	0.4730
25	1 56 31	−44 24 30	0.4040	24	2 35 46	−28 56 19	
27	1 59 19	−43 14 37		26	2 38 15	−28 3 48	0.4829
29	2 2 4	−42 5 48	0.4135	28	2 40 43	−27 12 25	
31	2 4 48	−40 58 6		Mar. 2	2 43 10	−26 22 9	0.4927
Feb. 2	2 7 30	−39 51 31	0.4232	4	2 45 37	−25 33 0	
4	2 10 10	−38 46 5		6	2 48 3	−24 44 57	0.5023
6	2 12 49	−37 41 48	0.4330	8	2 50 28	−23 57 58	
8	2 15 26	−36 38 41		10	2 52 52	−23 12 4	0.5118
10	2 18 2	−35 36 44	0.4430	12	2 55 16	−22 27 13	
12	2 20 37	−34 35 59		14	2 57 40	−21 43 25	0.5211

Sydney, New South Wales, 1898 *Dec.* 19.

LATITUDE-OBSERVATIONS MADE AT THE IMPERIAL ASTRONOMICAL OBSERVATORY AT KASAN,

BY M. A. GRATCHOF, OBSERVER OF THE OBSERVATORY.

[Communicated by Prof. D. I. DUBIAGO, Director.]

SERIES IV.

Date	φ 55° 47′+	Pairs	Date	φ 55° 47′+	Pairs	Date	φ 55° 47′+	Pairs
	″			″			″	
1897 July 13	23.07	14	1897 Dec. 7	23.31	17	1898 May 13	23.07	15
14	23.24	4	13	23.27	17	14	23.10	15
15	23.14	14	15	23.21	17	19	23.11	13
16	23.14	14	21	23.62	12	28	23.03	15
17	23.22	14	1898 Jan. 1	23.14	17	June 3	23.14	14
22	23.22	14	2	23.37	17	4	22.96	10
23	23.20	14	14	23.51	3	5	22.98	14
26	23.14	14	16	23.48	4	7	23.04	14
27	23.29	14	21	23.10	11	9	23.03	14
Aug. 10	23.05	15	23	23.26	17	11	23.05	14
11	23.15	15	26	23.04	17	13	22.98	14
16	23.26	15	Feb. 1	23.19	9	20	22.95	13
17	23.33	15	4	23.21	2	27	23.04	14
20	23.07	15	12	23.16	16	July 4	23.04	14
21	23.11	11	13	23.10	16	6	23.18	14
23	23.30	5	14	23.14	11	7	23.16	14
24	23.22	15	16	23.28	16	8	22.98	8
Sept. 10	23.26	15	19	23.20	16	18	23.01	13
12	23.14	12	22	23.18	16	25	22.97	14
22	23.26	17	Mar. 1	23.25	8	28	22.84	14
27	23.31	17	5	23.10	16	29	22.83	8
28	23.16	1	6	23.22	16	30	22.94	14
29	23.21	3	7	23.16	15	Aug. 4	23.21	15
Oct. 7	23.28	17	11	23.06	11	8	22.98	15
8	23.25	17	18	23.16	15	16	23.12	15
9	23.38	8	25	23.27	15	17	22.80	15
19	23.34	8	28	22.95	15	21	22.75	7
26	23.39	4	Apr. 4	23.09	15	24	23.20	15
Nov. 4	23.30	17	11	23.13	16	25	22.94	15
17	23.22	13	15	23.01	16	26	22.98	15
23	23.66	3	23	23.12	16	Sept. 12	23.13	15
25	23.42	8	30	22.88	9	13	23.18	8
Dec. 2	23.32	17	May 2	22.95	7	20	22.85	3
3	23.49	17	5	22.92	16	25	23.18	15
4	23.73	17	8	23.26	4	30	23.31	3
5	23.84	17	12	23.10	15			

MONTHLY MEANS.

Date		φ	Pairs	Date		φ	Pairs
1897 July 20	1897.55	55° 47′ 23″.18	116	1898 Mar. 13	1898.20	55° 47′ 23″.14	111
Aug. 17	63	23.18	106	Apr. 16	29	23.06	72
Sept. 19	72	23.25	65	May 11	37	23.05	100
Oct. 11	78	23.30	54	June 11	44	23.02	121
Nov. 14	87	23.32	41	July 17	54	23.00	113
Dec. 8	94	23.17	131	Aug. 17	63	23.02	112
1898 Jan. 11	1898.04	23.21	89	Sept. 18	72	55 47 23.15	14
Feb. 14	12	55 47 23.18	102				

PROVISIONAL REDUCTION.

Date	φ	Pairs	Date	φ	Pairs
1898 Oct. 2	55° 47′ 23″.18	8	Oct. 11	55° 47′ 23″.24	51
9	23.22	17			
10	23.13	9			
17	23.36	17			
Nov. 5	55 47 23.23	8	Nov. 14	55 47 23.38	54
9	23.32	16			
14	23.44	9			
22	23.46	15			
23	23.48	6			

EPHEMERIS OF COMET *j* 1898,

BY E. F. CODDINGTON.

From my elements, given in *A.J.* 453, I have computed the following ephemeris for this comet. The ephemeris for January, already published, from the same elements, is somewhat in error owing to the use of a wrong value of *B*, which should read 109° 18′ 4″.4 instead of as printed. The corrected ephemeris gives the following residuals for my recent observations with the 36-inch refractor:

O—C

Jan. 4, $\Delta\alpha = +0^s.19$ $\Delta\delta = +2''.2$
5, $\Delta\alpha = +0.17$ $\Delta\delta = +1.5$

EPHEMERIS FOR GREENWICH MIDNIGHT.

Gr. M.T. 1899	α	δ	log Δ	Br.
Jan. 31.5	11h 9m 3s.46	+34° 20′ 10″.6	0.2685	1.07
Feb. 2.5	8 33.94	34 41 14.5	0.2696	
4.5	7 59.15	35 1 41.3	0.2708	1.02
6.5	7 19.42	35 21 27.5	0.2723	
8.5	6 35.16	35 40 28.4	0.2740	0.99
10.5	5 46.74	35 58 39.5	0.2759	
12.5	4 54.58	36 15 56.7	0.2780	0.95
14.5	11 3 59.18	+36 32 17.2	0.2804	
Feb. 16.5	11 3 0.99	+36 47 38.3	0.2829	0.91
18.5	2 0.49	37 1 56.3	0.2857	
20.5	11 0 58.16	37 15 10.3	0.2886	0.87
22.5	10 59 54.48	37 27 17.4	0.2918	
24.5	58 49.87	37 38 16.7	0.2951	0.83
26.5	57 44.81	37 48 7.6	0.2987	
28.5	56 39.81	37 56 47.8	0.3024	0.79
Mar. 2.5	55 35.16	38 4 19.6	0.3062	
4.5	54 31.44	38 10 40.0	0.3103	0.75
6.5	53 29.03	38 15 50.6	0.3145	
8.5	52 28.31	38 19 50.9	0.3188	0.71
10.5	51 29.67	38 22 42.6	0.3233	
12.5	50 33.54	38 24 26.6	0.3278	0.67
14.5	49 40.26	38 25 2.3	0.3326	
16.5	48 50.19	38 24 32.9	0.3375	0.63
18.5	48 3.54	38 23 0.5	0.3425	
20.5	47 20.60	38 20 25.6	0.3475	0.59
22.5	46 41.55	38 16 52.1	0.3527	
24.5	46 6.59	38 12 20.8	0.3579	0.55
26.5	45 35.86	38 6 55.2	0.3632	
28.5	45 9.42	38 0 36.7	0.3686	0.51
30.5	44 47.38	37 53 28.5	0.3740	
Apr. 1.5	44 29.87	37 45 31.8	0.3795	0.48
3.5	10 44 16.87	+37 36 49.3	0.3851	

Mt. Hamilton, 1899 *Jan.* 14.

CONTENTS.

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THE FUNDAMENTAL LAW OF TEMPERATURE FOR GASEOUS CELESTIAL BODIES,

BY T. J. J. SEE.

(1). *Historical Statement.* It is proposed to discuss a very remarkable law of temperature which applies to all gaseous celestial bodies, and apparently throws a new light upon the processes by which the material universe has reached its present condition. If this law is somewhat less general, it is even more simple, than the law of gravitation; and hence it is highly proper to set forth with some detail the steps by which the results indicated below have been attained. As intimated in *A.J.* 453, the law was discovered by me (on May 6, 1898) while occupied with some researches on the heat of the sun intended for Vol. II of the "Researches on the Evolution of the Stellar Systems"; the immediate cause of the inquiry being the necessity of explaining the darkness of the companions of such stars as *Sirius* and *Procyon.* Having lost all manuscript papers by the fire of September 14, 1897, I secured from my friend, Professor ERIC DOOLITTLE of the Flower Observatory, a set of notes which he took on a course of lectures on the sun's heat, given at Chicago in the summer of 1895; and in supplying the lost lectures developed the theory of the heat given out by the condensation of a heterogeneous sphere. I then recognized for the first time the full significance of some computations which Professor DOOLITTLE had made for me in the summer of 1895. He showed that in the condensation of the solar nebula from infinite expansion very little energy had been generated by the contracting mass until it reached very small dimensions. Thus on the hypothesis of homogeneity it appeared that the heat produced before the solar nebula came within the orbit of *Mercury*, was only one eighty-third part of the total heat generated up to the present time; and as this indicated a rapid increase in the development of heat for a given shrinkage of radius, when the radius is small, I set for myself the problem to determine how the generation of heat varies with the radius of the condensing mass. Following the method of HELMHOLTZ it is easy to show that if H represent the total amount of heat generated by the mass in condensing from infinite expansion, R its radius, and C a certain constant, we shall have

$$\frac{dH}{dR} = -\frac{C}{R^2} \tag{1}$$

From this equation it was plain that the production of heat would become a maximum when R had attained the smallest value consistent with the laws of gaseous constitution. The next step was to prove the temperature law. Though discovered at first by a less direct process, it will be found below by an application of the most elementary principles. The simplicity of the temperature law was so great as to excite astonishment. On applying it to the heavens, I drew at once the body of the conclusions indicated below. The results were so startling that I hesitated to announce the law; besides, it was deemed desirable to ascertain if any work on similar questions had been done by previous investigators. Accordingly, I referred the question of a law connecting the temperature of a gaseous star with its radius to some fifteen of the most distinguished astronomers in the United States, without getting much additional light on the subject; and on July 4, sent a similar inquiry to an illustrious English friend, who of all men would presumably know of such a law if any had been discovered by previous investigators. In his reply, dated August 12, 1898, this classic authority says: "The only investigation which I can remember which goes mathematically into similar questions — though whether such a law is definitely stated I do not recollect — is the series of papers at some intervals by RITTER, about ten years ago in *Wiedermann's Annalen.*"

As the gentlemen consulted included several members of the distinguished Board of Editors of the *Astrophysical Journal*, all of whom expressed surprise at the simplicity of the result obtained, further search for early work on the law of temperature was deemed useless. Meantime my illustrious English friend, meditating on the announcement of July 4, that I had found a law connecting the tempera-

ture of a star with its radius, and that it seemed to have great significance for Astrophysics, sent a letter to one of the editors of the *Astrophysical Journal* suggesting that notice be made in that publication of this neglected work of RITTER. In making this review one of the editors found and made known to me on December 7, when I was visiting the Yerkes Observatory, that RITTER had stated in Vol. XIII of *Wiedemann's Annalen* a result similar to the one I had recently discovered and made known to astronomers. The theorem is there derived with a mass of other data, and stated in *language;* after which the author drops the matter and proceeds with other inquiries relative to atmospheres. So far as can be learned this result remained unknown to astronomers and astrophysicists, and it will be seen from the above narrative that RITTER's papers would have little chance of being known to-day but for the letter of July 4 to the illustrious British authority, which was the means of rescuing those writings from astronomical oblivion. These successive events explain the origin of the interesting papers now appearing in the *Astrophysical Journal.*

In 1869 Mr. J. HOMER LANE of Washington discussed the theory of the heat of the sun in a mathematical paper which was read to the National Academy of Sciences, and published in the *American Journal of Science* for July, 1870; and though he implies that the temperature of a gaseous mass may rise by condensation, there is no formula given, nor is there any specific statement of a law of temperature. This general result has gone into YOUNG's *General Astronomy* as "LANE's Law." It will be seen that the law of temperature $T = \frac{K}{R}$ is an exact formulation of what has passed as the general conclusion of LANE. In order to ascertain whether anything further could be determined regarding unpublished work of LANE, I inquired recently of Professor CLEVELAND ABBE, only to find that he had made an unsuccessful search for LANE's manuscripts some years ago. Consultation with Professor NEWCOMB elicited the information that he and LANE had discussed the heat of the sun in 1876, and that they agreed that the condensing mass could rise in temperature and grow hotter. NEWCOMB mentioned the matter to Lord KELVIN in a conversation at the Smithsonian Institution the same year, and it appears that this illustrious physicist afterwards recognized the correctness of the conclusions of LANE and NEWCOMB. It does not appear that any of these gentlemen published the law in a mathematical form, and so far as can be ascertained it appeared in that form for the first time in *A.J.* 453. The true historical statement thus seems to be:

(1). In stating the great principle of the conservation of energy, in a popular address delivered at Könisberg, February 7, 1854, HELMHOLTZ discusses the contraction of the sun's mass as the source of its heat (*Phil. Mag.*, 1856).

(2). In 1869 LANE goes mathematically into the theory of the gaseous constitution of the sun and implies in his discussion that the temperature may rise; but never publishes any law of temperature. NEWCOMB and LANE confer about this point in 1876, and the result is made known to Lord KELVIN, who recognizes the general conclusion reached by the American astronomers.

(3). While occupied with researches on atmospheres, about 1881, RITTER reaches independently an exact formulation of the theorem and publishes it in a Physical Journal, where it remains unknown to astronomers and astrophysicists.

(4). On May 6, 1898, while occupied with the heat of the sun and with the cause of the darkness of the companions of *Sirius* and *Procyon*, the writer discovers the law independently, states it generally as an exact formula, and derives from it conclusions of a far-reaching character. An English friend with whom he communicated, is the means of rescuing RITTER's work from astronomical oblivion; and the foregoing history of this remarkable law is at length brought to light. If further information regarding the history of this law should be developed, it will be noted in a later communication.

(II). *Derivation of the Law of Temperature,* $T = \frac{K}{R}$.

Suppose a gaseous globe of radius R_0 and temperature T_0 to be held in equilibrium by the pressure and attraction of its particles. Let the gravitational pressure per unit surface be P_0. Then suppose the globe by loss of heat to shrink to a radius R; the pressure per unit surface will become $P = P_0\left(\frac{R_0}{R}\right)^2$. The surface of the sphere on which the pressure of gravity is exerted will become $S = S_0\left(\frac{R}{R_0}\right)^2$. As the pressure per unit surface is increased, while the area of the surface is decreased, it is evident that the pressure per unit surface will become $[P] = [P_0]\left(\frac{R_0}{R}\right)^4$. But the density of the original mass was σ_0, and hence we have $\sigma = \sigma_0\left(\frac{R_0}{R}\right)^3$. By hypothesis the equilibrium of the globe is maintained by internal heat due to the gravitational shrinkage of the mass. If, therefore, the globe was in equilibrium when the mass had a temperature T_0, to remain in equilibrium in the condensed condition, T_0 must be multiplied by $\frac{R_0}{R}$. As T_0R_0 is a constant, we may write the law of temperature

$$T = \frac{K}{R} \tag{2}$$

This remarkable formula expresses one of the most fundamental of all the laws of Nature. Gravitation applies alike to all bodies, gaseous, liquid, and solid, and

whether cold or hot; the above law applies only to gaseous masses, but as the stars and nebulas of space in the main are assumed to be of a gaseous constitution, it has apparently the widest application in the actual universe. The stars and nebulas are self-luminous, and therefore of a fluid and in general of a gaseous nature. Since many of them are at high temperatures, the gaseous condition is the one most generally met with among the bodies observed in space.

(III). *Temperature of the Diffused Nebulas.* The constant K is always finite, and hence we see from the above law of temperature that when R is infinite, T is zero; thus the diffused nebulas are near the temperature of space, or approximately $-273°$ C. This may also be inferred from other considerations. If such diffused masses were appreciably heated they would soon cool off; and, besides, molecules on their outskirts having sensible molecular velocities would escape into interstellar space. How the light of such masses is maintained is not certainly known, but it is probably due to electric luminescence such as we observe in the tails of comets, which also shine at a temperature approaching the absolute zero. We may therefore suppose the diffused and irregular nebulas, as well as the milky nebulosity so abundantly scattered over the sky, to be intensely cold. It is an impressive fact that hydrogen and *nebulium* are the only elements recognized in the nebulas, and all other elements presumbly present are wholly nonluminous.

(IV). *The Temperature of Stars of the First Class.* The stars of the first spectral type are admitted to be at the highest temperatures known. This is inferred generally from the nature of the light emitted by these stars, and in the particular case of *Sirius*, is proved by the enormous radiation of that body compared to that of our sun. Thus, while the mass of *Sirius* is only about twice that of our sun, its radiation is shown to be forty or fifty times the greater of the two bodies. It follows therefore that the Sirian stars are intensely hot. By the above law of temperature such heat can be developed and such radiation maintained, only when the radius of the condensing mass is relatively small. The Sirian stars have therefore already shrunk to small bulk, and the contention hitherto current among astrophysicists, that the Sirian stars are of large bulk, and resemble nebulas, can no longer be supported. It is evident that such tremendous radiation as we observe, could not be maintained by the gravitational shrinkage of the mass, except when the radius is small, and the force of gravity correspondingly enormous. As respects volume therefore as well as temperature the Sirian stars are as far removed from the nebular condition as possible; and any spectral parallel between these two classes of objects should be explained in some other way. The diffuse nebulas are cold, infinitely rare, and almost free from pressure; the Sirian stars are intensely hot, dense, and subject to enormous gravitational pressure.

(V). *Stars of the Second Class.* Stars of the second class, of which our sun is an example, are conceded to be at lower temperatures than those of the first class, and the question arises whether their temperatures are rising or falling. The Sirian stars are surrounded by dense hydrogen atmospheres, which produce the heavy absorption observed in their spectra. As the heights of atmospheres of gases of different molecular weights under any given condition are known to be inversely as the molecular weights, it follows that when a star is so far condensed that gravity is intense, the outer atmosphere ought to be of hydrogen, such as we observe in the Sirian stars. The heavier elements in the Sirian stars are pressed down by gravity, and their spectral lines are either faint, or entirely absent. Now if our sun had already passed through the Sirian stage, and the temperature was falling, the hydrogen atmosphere which had been separated from the other elements by the effects of gravity ought still to surround its globe. As all the elements in the sun are fairly evenly mixed, such heavy vapors as calcium and iron mixing freely with those of light elements like hydrogen and helium, we infer that our sun has not yet passed through the Sirian stage of development. The lower temperature of solar stars thus indicates an earlier condition than that met with in the Sirian stars.

(VI). *Stars of the Third Class.* If the above considerations be valid, it will follow that the orange stars are at a still earlier stage of development than the solar stars. Further considerations of the spectral classification are reserved for a future communication.

(VII). *The Sun will eventually become Blue.* The secular shrinkage of the sun's radius will cause a steady rise in its temperature, and when the body has reached the stage of *Sirius* it will shine with an intensely blue light, like that emitted by stars of the first class. The temperature will go on rising till a small radius is attained, and finally when the dense mass, intensely hot, becomes incapable of further shrinkage, from increase of resistance in the molecular forces, a cooling and liquefaction will rapidly take place. A condition of darkness thus follows close upon a period of intense brilliancy; and hence the darkness of such bodies as the companions of *Sirius*, *Procyon* and *Algol*. Here the smaller masses, as in the solar system, have developed most rapidly.

(VIII). *The Earth Received More Heat in Geological Times than at Present.* Though the sun's temperature will steadily rise as its radius shrinks, the area of its disc will diminish in more than corresponding degree. Now the amount of heat received by a given area on the earth's surface depends on the size of the sun's disc, as well as on its temperature. Thus, as the size of the disc is propor-

tional to the square of the sun's radius, while the temperature is inversely as the radius, it follows that the heat received by the earth will experience a secular diminution proportional to the contraction of the sun's radius. In geological times the earth was warmer than at present, which in general accords with known phenomena.

(IX). *Present and Past Temperatures of the Sun.* If we adopt the effective temperature of the sun experimentally determined by WILSON and GRAY (*Phil. Trans.*, 1894), which is about 8000° C, we see that when the sun's radius was twice as great as at present, the effective temperature, by the above law, was about 4000° C; and when the radius had eight times its present value, the temperature was only 1000° C, which would not fuse the more refractory metals. The following table shows the effective temperature of the solar nebula when it extended to the several planets:

	[Absolute Temperature]
Present solar surface	8000° C.
Mercury	92°
Venus	53°
Earth	40°
Mars	24°
Jupiter	7°
Saturn	4°
Uranus	2°
Neptune	1°

The excessively low temperatures of the solar surface when it reached the orbits of the several planets must excite our astonishment. The temperature was always much below zero, and the density of the mass necessarily very small.

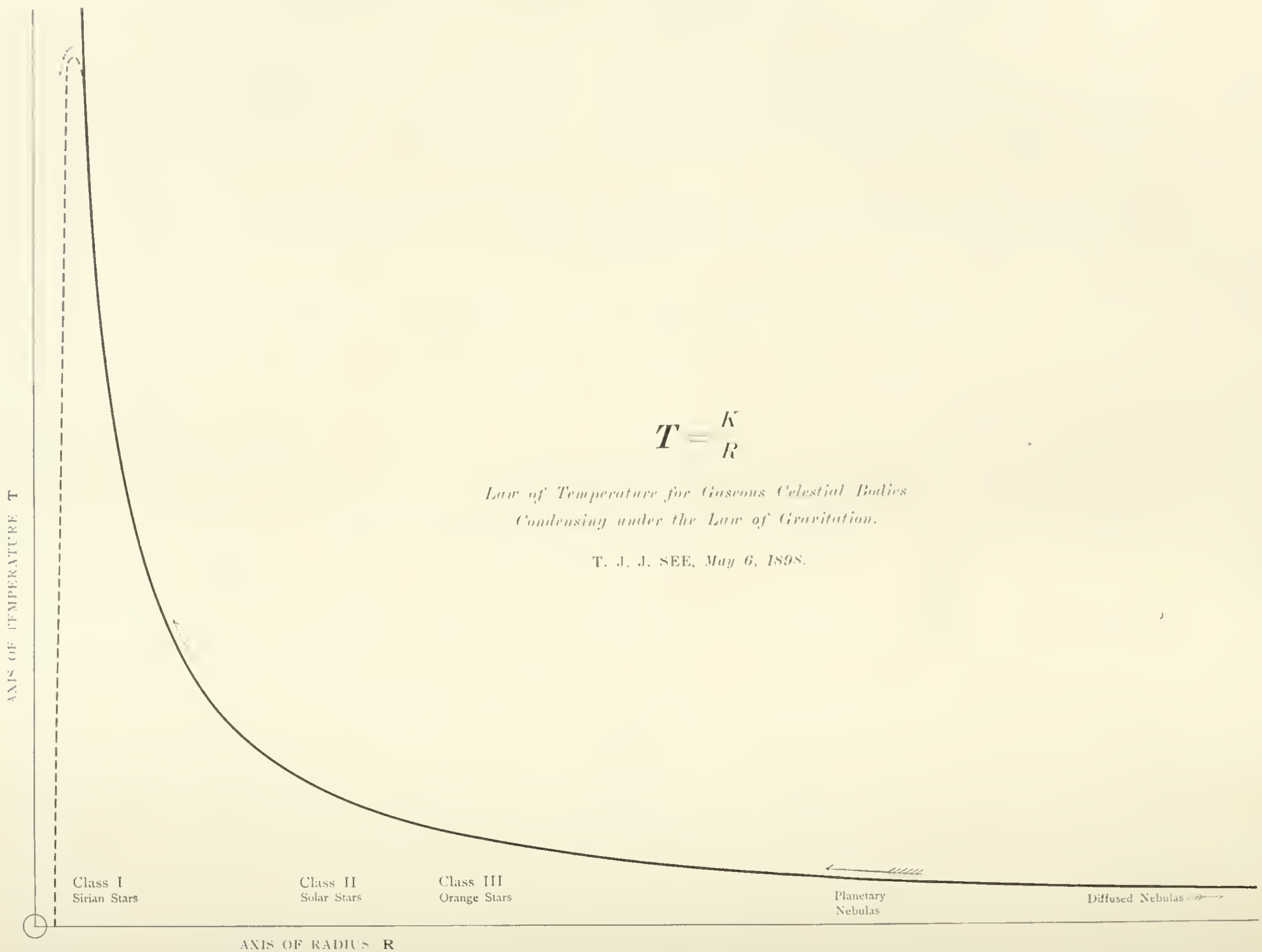
It is worthy of remark that as the present density of the sun is about 1.4, a contraction to one-half its present radius, which would give a temperature of 16,000° C, if the mass still remains gaseous, would make the density about 11.2; further shrinkage under gaseous conditions is hardly conceivable, and hence it is probable that the temperature of the Sirian stars is from 10,000° C to 20,000° C.

(X). *The Internal Temperature of the Earth.* As the lunar-terrestrial mass was very cold (−233° C) when separated from the sun, it follows that what heat we observe in the interior of the globe, must have arisen from the shrinkage of its original volume. We do not know the diameter of the nebular earth, but it is very unlikely to have exceeded the dimensions of the lunar orbit; and with this rough approximation, it is difficult to see how the internal temperature of the earth can have exceeded something like 1000° C. Moreover, it probably does not increase after a certain depth has been reached, but then remains essentially uniform throughout the interior of the globe. Contrary as it may seem to old theories like those of LAPLACE and POISSON, there is no evidence that the temperature of the earth ever surpassed the melting point of lava and of the more refractory rocks. The retention of the terrestrial atmosphere is direct evidence that the primitive heat was very moderate. This result will have no slight bearing on the theories of geology.

(XI). *Temperatures of the Great Planets.* As experiments upon the secular shrinkage of great masses cannot be made in our laboratories, it is fortunate that the solar system offers to our observation large as well as small planets of approximately the same absolute age. We find the smaller planets, such as the *Earth*, *Venus*, *Mars* and *Mercury*, already solid, while the great planets *Jupiter*, *Saturn*, *Uranus* and *Neptune* are apparently still gaseous if not actually rising in temperature. The law of temperature shows that if bodies like *Jupiter* and *Saturn* are gaseous they have not been hot in the past, but may become so hereafter. There is some spectral indication of inherent luminosity in *Uranus*, and hence all the great planets are probably still rising in temperature. As the temperatures of these masses were originally near the absolute zero of space, we are not to think of them as cooling, but rather as having slowly heated up ever since their separation from the solar nebula. The inferences of KANT, ZÖLLNER and PROCTOR, as well as the original assumption of LAPLACE, are wholly unauthorized. It is possible, and perhaps even probable, that some of the great planets, especially *Jupiter*, may eventually become self-luminous.

The excessively low temperatures given in the foregoing table show that the matter which formed the planets must have been essentially solid when these bodies were separated from the solar mass. If on the one hand these considerations indicate how little is known of the real process involved in the formation of our planetary system, they point the way, on the other, to lines of inquiry which future investigators should follow.

(XII). *Conclusions.* It is somewhat remarkable that while the law of gravitation causes bodies to describe conic sections, the law of temperature for every gaseous body is represented by a rectangular hyperbola referred to its asymptotes, and thus by a particular curve of the same general species. The law $T = \frac{K}{R}$ apparently has the widest significance, and should be taken account of in future researches on the temperatures and relative ages of the stars. The interpretation of spectral phenomena should at least conform to the more fundamental laws of gravitation and of temperature. In view of the undoubted high temperature of the Sirian stars, it is not possible to deny that they are shrunk to small bulk. Nothing could be more unwarranted than to connect such hot objects with the cold nebulas which shine by some process of electric luminescence. The nature of the temperature-curve leads one to think that the cooling stage of a star's life will be very short — approximately the time required for such a



CURVE OF TEMPERATURE FOR GASEOUS STARS AND NEBULAS. A RECTANGULAR HYPERBOLA REFERRED TO ITS ASYMPTOTES.

hot globe to cool, when the source of heat is removed and the mass is allowed to radiate without shrinking — which is to be reckoned at most in decades or centuries rather than in millions of years.

In view of the diversity of opinion already held by distinguished astronomers, and the indifference with which new theories are usually received, it will be understood that the suggestions here thrown out have not been made from any mere love of novelty. It is hoped that some progress can be made in a future paper towards reconciling known spectral phenomena with the fundamental law of temperature.

Cambridge, Mass., 1899 *January* 22.

OBSERVATIONS OF THE SATELLITES OF *SATURN*,

MADE WITH THE 26-INCH REFRACTOR OF THE LEANDER McCORMICK OBSERVATORY, UNIVERSITY OF VIRGINIA.

BY J. ADAIR LYON.

The angles given are each the mean of two comparisons The distances were obtained from measures of double distances. Corrections for refraction have been applied.

Enceladus–Tethys.

1898	Eastern Time	p	Eastern Time	s
	h m s	°	h m s	″
Apr. 21	15 55 29	343.23	16 0 39	18.54
	16 8 57	347.25	16 3 46	18.02
May 17	15 13 5	164.64	15 19 21	10.77
	15 35 12	167.50	15 26 9	11.49
31	11 56 31	50.72	12 2 56	28.59
	12 19 32	54.95	12 8 12	28.21
June 5	13 30 32	101.19	13 38 26	27.38
	13 50 43	101.27	13 44 11	28.24
7	13 41 17	230.81	13 47 52	31.90
	13 57 5	233.15	13 51 48	31.99

Enceladus–Dione.

1898	Eastern Time	p	Eastern Time	s
May 9	12 50 30	126.52	13 1 52	41.03
	13 14 39	128.84	13 6 28	40.40
31	12 27 39	142.98	12 33 59	34.37
	12 45 35	146.21	12 37 46	33.96
June 7	14 6 33	90.09	14 15 0	57.15
	14 24 0	90.80	14 19 2	56.76
14	11 15 24	230.91	11 20 54	45.98
	11 57 0	235.84	11 24 7	44.83

Enceladus–Rhea.

1898	Eastern Time	p	Eastern Time	s
Apr. 21	16 15 23	281.86	16 20 7	46.13
	16 29 17	282.31	16 24 20	46.57
May 9	13 27 19	261.07	13 35 15	37.02
	13 46 23	263.78	13 40 31	36.82
June 9	12 7 18	253.03	12 13 45	74.67
	12 23 19	253.56	12 18 44	74.24

Tethys–Dione.

1898	Eastern Time	p	Eastern Time	s
	h m s	°	h m s	″
Apr. 20	15 25 31	262.88	15 31 7	76.41
	15 39 46	263.67	15 35 25	76.65
29	13 40 31	269.73	13 47 3	49.83
	13 55 33	270.00	13 51 51	50.45
May 9	13 54 21	255.17	14 0 43	49.34
	14 13 1	256.70	14 5 19	49.35
June 5	14 17 33	279.53	14 23 56	71.32
	14 33 46	280.15	14 29 17	71.62
9	12 45 48	344.95	12 53 12	16.21
	13 0 26	347.82	12 56 18	16.31
	13 20 1	351.82	13 24 43	15.34
	13 30 45	354.93	13 26 48	15.30
14	12 0 22	272.84	12 4 5	81.07
June 14	12 10 41	273.34	12 7 32	81.36
21	10 33 11	106.57	10 39 33	43.15
	10 49 16	107.35	10 43 33	43.21
Sept. 1	8 0 34	206.02	8 4 28	38.13
	8 15 12	209.33	8 6 54	38.42

Tethys–Rhea.

1898	Eastern Time	p	Eastern Time	s
Apr. 20	14 39 53	241.36	14 47 36	58.75
	14 57 19	242.74	14 52 43	58.86
June 9	12 28 46	163.14	12 33 52	24.99
	12 40 25	164.94	12 37 0	24.86
	13 36 34	171.84	13 41 31	25.87
	13 48 8	173.18	13 44 8	26.14
21	10 56 3	103.99	11 1 22	65.65
	11 11 1	104.04	11 4 43	65.61
Sept. 1	7 42 5	74.30	7 47 54	25.36
	7 55 40	73.15	7 51 18	25.62

Dione–Rhea.

1898	Eastern Time	p	Eastern Time	s
Apr. 20	15 5 49	125.36	15 11 7	26.82
	15 19 55	125.28	15 15 43	26.82
May 9	14 23 46	288.81	14 30 35	71.92
	14 47 17	288.94	14 35 2	71.84
17	15 53 7	228.87	16 1 30	15.82
	16 10 3	229.02	16 6 0	15.85
June 5	14 40 22	277.08	14 48 20	40.48
	14 57 35	277.17	14 53 2	40.40
	15 1 59	277.14	15 6 54	39.73
	15 16 24	277.06	15 11 40	39.57
7	14 27 0	83.90	14 32 14	22.48
	14 39 2	83.94	14 35 44	22.19
13	9 10 20	216.11	9 15 14	39.55
	9 22 25	217.89	9 17 53	39.31
14	10 54 43	271.57	10 59 7	25.48
	11 7 31	271.81	11 4 17	25.48
	12 13 31	270.77	12 18 29	24.37
	12 28 29	269.14	12 23 39	23.94
21	9 50 11	97.67	9 55 19	24.96
	10 2 47	97.13	9 58 49	25.17
	11 38 20	95.99	11 41 47	23.81
	11 47 25	95.20	11 44 7	24.04

Rhea–Titan.

1898	Eastern Time	p	Eastern Time	s
June 21	10 13 53	43.28	10 19 55	64.62
	10 26 0	43.16	10 22 31	65.01
	11 50 34	43.13	11 54 49	67.54
	12 1 35	43.72	11 58 7	68.16

Charlottesville, October 1, 1898.

SUNSPOT OBSERVATIONS,

MADE AT BERWYN, PENNA., WITH A 4½-INCH REFRACTOR,

BY A. W. QUIMBY.

1898	Time	New Grs.	Total Grs.	Total Spots	Fac Grs.	Def.
July 1	7	–	1	6	2	fair
2	7	–	1	1	2	fair
3	7	–	–	–	2	fair
4	7	–	–	–	2	fair
5	7	–	1	1	2	fair
6	7	–	–	–	2	fair
7	7	–	–	–	3	fair
8	7	–	–	–	1	fair
9	7	–	–	–	–	fair
10	7	–	–	–	–	fair
11	7	–	–	–	1	good
12	8	–	–	–	–	poor
13	3	–	–	–	–	poor
14	9	–	–	–	–	poor
15	6	–	–	–	–	poor
16	7	1	1	4	–	fair
17	7	–	1	2	2	fair
18	7	–	–	–	–	fair
19	9	1	1	3	1	fair
20	7	–	1	4	1	poor
21	7	–	1	6	2	fair
22	7	1	2	6	1	fair
23	12	–	1	6	1	poor
24	2	–	1	7	1	poor
25	3	1	2	9	2	fair
26	9	–	2	8	2	fair
27	10	–	–	–	1	poor
28	11	–	–	–	–	poor
29	11	1	1	10	–	fair
30	10	–	1	10	–	fair
31	10	2	3	44	2	good
Aug. 1	7	1	4	30	2	fair
2	7	1	4	39	2	fair
3	7	–	3	30	–	poor
4	7	–	3	45	2	fair
5	8	–	3	23	1	poor
6	3	–	3	48	2	good
7	8	–	3	27	1	fair
8	7	–	2	45	–	good
9	7	–	2	34	–	fair
10	8	–	2	15	–	poor
11	11	–	2	23	–	poor
12	3	1	3	26	1	fair
13	8	1	3	15	1	poor
14	8	–	2	30	1	fair
15	7	1	3	21	1	fair
*16	7	–	1	6	2	poor
*17	9	–	1	2	1	poor
*18	7	–	1	1	1	poor
*20	7	–	–	–	–	good
*21	7	–	–	–	–	fair
*22	7	1	1	3	1	fair
23	5	–	1	3	1	fair
24	8	–	1	1	1	fair
25	8	–	–	–	1	fair
26	8	2	2	10	1	fair
Aug. 27	8	–	2	6	1	poor
28	8	–	2	5	1	fair
29	9	–	2	3	2	fair
30	8	–	1	1	–	fair
31	8	–	1	2	2	fair
Sept. 1	8	1	2	4	2	fair
2	8	–	1	1	1	fair
3	8	1	2	5	2	fair
4	8	–	2	7	1	fair
5	8	–	2	15	1	fair
6	4	–	2	67	1	v.good
7	8	–	2	32	3	fair
8	8	–	2	61	1	fair
9	3	–	1	95	1	v.good
10	4	–	1	62	1	fair
11	8	–	1	56	1	fair
12	8	–	1	38	1	fair
13	8	–	1	68	1	good
14	8	–	1	10	1	poor
15	8	1	2	9	1	poor
16	8	1	2	13	1	poor
17	8	–	2	30	–	fair
18	8	–	2	8	1	fair
19	7	–	2	11	1	fair
20	8	–	1	8	1	fair
21	8	–	1	7	2	fair
22	8	–	1	4	–	poor
23	5	1	2	7	1	fair
24	8	–	2	8	1	fair
26	10	1	2	6	–	poor
27	8	–	2	19	–	fair
28	8	1	3	20	1	fair
29	8	–	2	26	1	fair
30	8	1	3	30	1	fair
Oct. 1	8	–	3	38	1	fair
2	12	–	3	39	2	fair
3	8	–	3	16	–	poor
4	8	–	3	20	–	fair
5	12	–	3	11	1	poor
6	8	–	3	23	2	good
7	8	1	3	34	2	good
9	8	–	3	30	2	good
10	8	–	3	9	2	fair
11	8	–	2	9	2	poor
12	8	–	2	15	1	poor
13	8	1	2	6	2	fair
14	9	–	2	8	1	poor
15	8	–	2	4	1	poor
16	8	–	2	8	3	good
17	8	–	2	10	1	fair
18	8	–	1	1	–	poor
19	10	–	–	–	1	poor
20	8	–	1	2	–	fair
21	8	–	–	–	–	poor
22	11	1	1	4	2	poor
23	8	–	1	14	2	fair
Oct. 24	8	–	2	24	2	fair
25	8	1	2	24	1	fair
27	8	1	3	22	1	fair
28	8	1	4	54	1	fair
29	8	–	3	15	–	poor
31	8	1	4	25	1	poor
Nov. 1	8	1	4	51	3	good
2	8	1	5	34	2	fair
3	8	–	5	50	2	good
4	8	–	4	79	2	v.good
5	2	–	4	60	2	fair
6	1	–	4	25	1	poor
7	8	–	4	35	1	fair
8	9	–	3	12	–	poor
9	10	–	2	7	1	poor
11	8	1	3	10	1	poor
12	9	–	3	7	1	fair
13	2	–	1	4	–	poor
14	12	–	1	3	–	poor
15	8	–	1	10	–	good
16	3	–	–	–	–	poor
19	4	1	1	3	–	poor
20	8	–	1	10	1	v.good
21	7	–	1	2	–	poor
22	8	–	1	2	1	fair
25	9	–	1	1	1	fair
27	8	–	–	–	–	poor
28	8	2	2	2	1	poor
29	8	–	2	4	–	poor
30	3	–	2	4	1	good
Dec. 1	9	–	2	12	1	fair
2	8	1	2	3	–	poor
5	12	–	2	4	–	poor
6	10	–	2	4	–	poor
7	9	–	2	18	–	fair
8	8	–	2	16	–	poor
9	9	–	2	12	–	poor
10	10	–	1	5	1	poor
11	8	–	1	4	–	fair
12	8	–	1	3	–	poor
13	9	–	1	3	2	fair
14	9	–	–	–	1	good
15	9	–	–	–	–	fair
16	8	1	1	1	1	fair
17	8	–	–	–	–	v.poor
18	9	1	1	4	1	fair
19	8	–	1	3	–	poor
22	8	–	–	–	–	poor
23	11	–	–	–	–	poor
24	9	–	–	–	–	fair
25	8	–	–	–	–	poor
26	10	–	–	–	–	fair
27	9	–	–	–	–	fair
28	9	1	1	4	3	fair
29	11	1	1	1	2	poor
30	–	–	–	–	–	poor

* 2½-inch refractor.

OBSERVATIONS OF MINOR PLANETS AND COMET *i* 1898,

MADE AT THE OBSERVATORY OF VASSAR COLLEGE WITH THE 12-INCH REFRACTOR,

BY MARY W. WHITNEY AND CAROLINE E. FURNESS.

Greenwich M.T.		✱	No. Comp.	Planet — ✱ Δα	Planet — ✱ Δδ	Planet's Apparent α	Planet's Apparent δ	log Δp for α	log Δp for δ	Obs.
					(261) Prymno.					
1897	h m s			m s	′ ″	h m s	° ′ ″			
Nov. 27	18 16 14	1	8	+2 9.69	+ 7 30.0	4 35 37.00	+19 2 39.6	9.174	0.542	F
29	16 14 6	1	9	+0 1.01	+ 5 57.4	4 33 28.35	+19 1 7.1	*n*8.884	0.532	F
30	15 23 23	1	7	−1 4.28	+ 5 12.7	4 32 23.08	+19 0 22.4	*n*9.221	0.547	F
Dec. 15	16 55 12	2	8	+1 47.29	− 8 4.7	4 16 5.37	+18 51 22.7	9.223	0.544	F
					(247) Eukrate.					
1898										
Jan. 24	15 1 5	3	6	−0 40.03	+ 3 25.4	7 22 2.34	+60 44 15.9	*n*9.359	*n*0.435	W
					(213) Lilaea.					
Feb. 12	16 46 54	4	7	−1 1.21	+ 1 3.8	9 7 45.01	+19 9 51.8	8.528	0.527	W
16	17 26 48	5	9	+0 27.89	+ 5 2.8	9 4 19.82	+19 30 54.4	9.185	0.535	W
17	14 22 5	5	7	−0 15.13	+ 9 24.2	9 3 36.81	+19 35 15.8	*n*9.315	0.547	W
					(306) Unitas.					
Feb. 16	18 11 1	6	8	−1 25.52	+ 5 5.1	9 2 25.29	+16 18 38.8	9.368	0.604	F
					(207) Hedda.					
Feb. 16	18 43 6	7	8	−0 34.36	+ 2 19.6	9 15 23.29	+22 25 44.0	9.441	0.525	F
					(16) Psyche.					
May 9	15 18 46	8	9	+2 33.90	+ 0 18.9	14 33 34.62	−10 38 43.1	*n*9.055	0.841	F
13	14 25 33	9	9	+1 14.86	+ 1 43.8	14 30 33.42	−10 24 25.2	*n*9.249	0.836	F
14	15 16 1	9	9	+0 28.77	+ 5 22.0	14 29 47.33	−10 20 47.0	*n*8.867	0.841	F
					COMET *i* 1898.					
Nov. 3	11 49 56	10	6	−1 34.69	− 5 20.6	17 25 56.59	+22 45 10.9	9.638	0.636	W
4	12 33 59	11	5	−2 5.18	+ 7 12.7	17 30 37.69	+20 26 30.4	9.660	0.693	W
7	12 41 10	12	6	+2 13.23	− 2 54.8	17 41 54.01	+14 24 25.0	9.649	0.727	W
8	12 0 28	13	7	−0 13.61	− 8 5.6	17 44 55.69	+12 39 39.2	9.623	0.714	W
					COMET *i* 1898.					
Nov. 3	12 43 55	10	7	−1 24.37	−10 21.1	17 26 6.91	+22 40 10.4	9.671	0.691	*AE
4	13 19 17	11	8	−1 57.61	+ 3 8.2	17 30 45.26	+20 22 25.9	9.672	0.731	*AE

Mean Places for 1897.0 and 1898.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
1897	h m s	s	° ′ ″	″	
1	4 33 21.77	+5.54	+18 54 53.9	+15.7	Auwers, Berlin A.G. Catal. 1253
2	4 14 12.42	+5.66	+18 59 9.5	+17.9	Auwers, Berlin A.G. Catal. 1139
1898					
3	7 22 37.43	+4.94	+60 40 48.2	+ 2.3	Krueger, Helsingfors-Gotha A.G. 5107
4	9 8 43.27	+2.95	+19 8 57.4	− 9.4	Auwers, Berlin A.G. 3733
5	9 3 48.94	+2.99	+19 26 0.8	− 9.2	Auwers, Berlin A.G. 3695
6	9 3 47.88	+2.93	+16 13 43.2	− 9.5	Auwers, Berlin A.G. 3696
7	9 15 54.59	+3.06	+22 23 34.2	− 9.8	Becker, Berlin A.G. 3732
8	14 30 57.35	+3.37	−10 38 43.6	−18.4	Munich II, 5377
9	14 29 15.17	+3.39	−10 25 50.5	−18.5	Schjellerup 5171
10	17 27 29.49	+1.79	+22 50 26.4	+ 5.1	Becker, Berlin A.G. 6014
11	17 32 40.98	+1.89	+20 19 12.5	+ 5.2	Becker, Berlin A.G. 6043
12	17 39 38.69	+2.09	+14 27 15.3	+ 4.5	Greenwich 1880 Catal. 2795
13	17 45 7.14	+2·16	+12 47 40.2	+ 4.6	Schjellerup 6409

* ALICE EVERETT.

OBSERVATIONS OF COMET *j* 1898 (CHASE).

MADE WITH THE 12 AND 36-INCH REFRACTORS OF THE LICK OBSERVATORY,

BY E. F. CODDINGTON.

1898 Mt. Hamilton M.T.	*	No. Comp.	☌ − * $\Delta\alpha$	☌ − * $\Delta\delta$	☌'s apparent α	☌'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
Dec. 2 14h 21m 20s	1	8 , 8	+0m 9.40s	−1′ 31.8″	10h 34m 27.87s	+24° 25′ 37.4″	n9.594	0.473
7 13 5 13	3	8 , 8	+0 38.90	−2 7.5	40 49.84	24 58 32.9	n9.675	0.562
7 13 43 54	4	8 , 8	−0 6.03	−7 33.5	40 51.72	24 58 44.8	n9.636	0.506
8 13 1 59	5	8 , 8	+0 35.25	+1 3.9	42 3.05	25 5 42.6	n9.676	0.562
9 15 4 45	6	8 , 8	+0 16.03	+2 47.0	43 20.80	25 13 45.7	n9.476	0.374
10 13 3 45	8	6 , 10	−0 1.83	+1 39.7	44 25.13	25 20 31.0	n9.671	0.548
10 14 42 23	8	10 , 8	+0 3.22	+2 11.7	44 30.18	25 21 3.0	n9.525	0.400
11 12 57 37	10	10 , 10	+0 30.06	+5 47.4	45 34.26	25 28 6.6	n9.674	0.552
11 13 41 41	11	10 , 10	−0 22.89	−1 58.2	45 36.49	25 28 25.3	n9.626	0.485
16 15 30 4	13	8 , 8	−0 12.01	−1 12.5	51 4.92	26 9 44.0	n9.328	0.289
21 14 36 53	15	8 , 8	+0 36.66	+2 22.5	10 55 49.37	+26 54 4.2	n9.463	0.322

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	10h 34m 14.22s	+4.25s	+24° 27′ 38.0″	−28.8″	12M. Connected with *2
2	35 46.68	4.24	24 29 37.4	28.9	Becker, Berlin A.G. Catal. 4078
3	40 6.58	4.36	25 1 10.5	30.1	Graham, Cambridge A.G. Catal. 5487
4	40 53.39	4.36	25 6 48.4	30.1	Graham, Cambridge A.G. Catal. 5493
5	41 23.42	4.38	25 5 9.0	30.3	11M. Connected with *4
6	43 0.37	4.40	25 11 29.3	30.6	10M. Connected with *7
7	40 56.96	4.42	25 12 33.9	30.5	Graham, Cambridge A.G. Catal. 5495
8	44 22.53	4.43	25 19 22.3	31.0	10M. Connected with *9
9	46 20.97	4.41	25 17 16.4	31.0	Graham, Cambridge A.G. Catal. 5529
10	44 59.74	4.46	25 22 50.4	31.2	DM.+25°2307, 9M.1. Connected with *9
11	45 54.92	4.46	25 30 54.8	31.3	11M. Connected with *12
12	47 4.98	4.45	25 37 35.7	31.4	Graham, Cambridge A.G. Catal. 5537
13	51 12.31	4.62	26 11 29.3	32.8	10M. Connected with *14
14	51 41.99	4.61	26 7 42.6	32.8	Graham, Cambridge A.G. Catal. 5566
15	10 55 7.96	+4.75	+26 52 15.6	−33.9	Graham, Cambridge A.G. Catal. 5587

The observations of Dec. 2 and Dec. 16 were made with the 36-inch refractor; all others with the 12-inch telescope. An observation of Jan. 19, 1899, compared with the corrected ephemeris of *A.J.*, No. 453, gives residuals as follows:

Mt. Hamilton, 1899 *Jan.* 23. O−C, $\Delta\alpha = -1^s.51$, $\Delta\delta = +1''.3$

OBSERVATIONS OF OCCULTATIONS OBSERVED DURING THE TOTAL ECLIPSE OF THE MOON, DEC. 27, 1898,

BY ORMOND STONE.

* No. B.D.		Mag.	α app.	δ app.	Ingress or Egress	Greenwich M.T.	Notes
23°	1415	9.3	6h 29m 51.71s	+23° 1′ 56.0″	Ingress	10h 47m 54.2s	
23	1416	9.4	29 53.23	23 0 58.3	Ingress	10 48 26.9	
23	1416	9.4	30 47.24	23 4 53.5	Ingress	11 13 44.3	poor
23	1425	7.4	30 37.67	23 10 48.6	Ingress	11 14 45.8	good
22	1392	9.1	29 3.42	22 56 19.6	Egress	11 22 29.4	good
22	1392	9.4	31 4.04	23 7 31.0	Ingress	11 23 3.7	poor
22	1392	9.4	30 58.56	22 48 23.9	Ingress	11 36 9.1	
22	1410	7.7	6 31 35.15	+22 48 3.9	Ingress	11 55 29.4	

Leander McCormick Observatory, University of Virginia, 1898 *Dec.* 29. Clouds prevented me from seeing other occultations.

CONTENTS.

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NOTE ON SEE'S ARTICLE IN *A.J.* 455,

By A. S. CHESSIN.

Allow me to observe with regard to Dr. SEE's "remarkable" law, which he discusses at length in the last number of the *Journal*, that it is derived by the author with a superb neglect of the principles of hydrodynamics. The last stage of the "proof" is especially curious, as the assertion that T_0 must be multiplied by $\frac{E}{E}$ in order to preserve the equilibrium is nothing else than an assumption of that very "law" which Dr. SEE proposes to derive.

NOTES ON VARIABLE STARS. — No. 27,

By HENRY M. PARKHURST.

Change of Factors. The system of factors for the light-curve was based, in Notes No. 17 (No. 400 *A.J.*), upon the osculation of parabolic curves. The branches of the light-curve are generally much straighter than of the parabolic curve; making the tabulated correction for curvature too small near the vertex and too large at a distance from it. Hence it has been necessary, when the intervals were excessive, or the factors very small, to ascertain the proper correction for curvature by other unsatisfactory means. Substituting for the parabolic formula the following $T = qD^{\frac{2}{3}}$, q being the new Sesquibolic factors, (designated in the headings for the sake of distinction "S Factors,") and D being the difference in *hundredths* of a magnitude, we have a much closer approximation to the average curve, and equally convenient reduction. The adoption of the 1½ root, intermediate between the parabola and the straight line, leads to a modification of the subtangent principle; for the subtangent is 1½ times the abscissa; *i. e.*, the subtangent is trisected at the vertex.

RS Herculis. Perry's first observation is assumed to correspond with YENDELL's second max. (*A.J.* 388). The minimum is the mean of 90 days interval of equal magnitudes. Combining with YENDELL's observations I deduce a provisional period of 220 days.

RESULTS OF OBSERVATIONS.

No.	Star	Phase	Observed Date Julian	Observed Date Calendar	E	Corr.	W	Mag.	S Factors			Remarks
				1898							d	
5614	*Z Librae*	Max.	4484	July 13	25	–	E	–	–	–	–	Perhaps 20 days earlier
5770	*R Herculis*	Max.	4497.5	July 26	38	–28	9	8.21	0.88	1.26	24	Factors very much changed
5831	*S Scorpii*	Max.	4466	June 25	126	+10	5	11.47	–	–	–	Possibly much earlier
5860	*U Scorpii*	–	–	–	–	–	–	–	–			Results for three years
5887	*V Ophiuchi*	Max.	4434	May 24	29	– 8	3r	7.8	–	–	–	Assumed after May 17
5931	*S Ophiuchi*	Max.	4453	June 12	64	– 5	3r	10.3	–	–	–	Assumed after June 9
"	"	Max.	4463	June 22	64	+ 5	5	10.4	–	–	–	Possibly earlier
6044	*S Herculis*	Min.	4463	June 22	50	+ 4	5	12.4	–	–	–	– 16, by transition ele. 388
6132	*R Ophiuchi*	Min.	4491	July 20	50	–	E	–	–	–	–	At least a month earlier
6160	*RT Herculis*	Max.	4417	May 7	2	–	E	9.6	–	–	–	Period suggested *A.J.* 421
6207	*Z Ophiuchi*	Min.	4550 :	Sept. –	6	+37:	1	–	–	–		
6225	*RS Herculis*	Max.	4435	May 25	–	–	2	7.9	–	–	–	See note above
"	"	Min.	4561	Sept 28	–	–	2	12.0	–	–	–	See note above

No.	Star	Phase	Observed Date Julian	Calendar	E	Corr.	W	Mag.	S Factors			Remarks
				1898							d	
6512	*T Herculis*	Max.	4462	June 21	67	+15	7p	7.8	–	–	–	Confirms corr. by a different observer and different method
"	"	Max.	4627.7	Dec. 3	68	+16	9	7.19	0.70	0.64	14	
6624	*T Serpentis*	Max.	4574	Oct. 11	40	−25	6	9.61	0.94	1.39	30	
6849	*R Aquilae*	Min.	4534	Sept. 1	46	+61	9	11.85	2.21	1.67	60	+3, by sine ele. 365
6871	*V Lyrae*	Max. A	4575	Oct. 12	5	−10	7	9.79	1.56	1.19	31	Principal max.
"	"	Max. B	4604	Nov. 10	5	+19	5	10.00	–	–	–	See *A.J.* 393 and 421
6888	*RW Sagittarii*	–	–	–	–	–	–	–	–	–	–	Fluctuat'n; perhaps short period
6892	*RX Sagittarii*	–	4418	May 8	–	–	E	–	–	–	–	From prov. period 320 days
6894	*S Lyrae*	Max.	4380	Mar. 31	4	–	E	–	–	–	–	Obsns. tend to confirm period
6900	*W Aquilae*	Max.	4584	Oct. 21	3	+ 8	9	10.31	1.03	1.22	22	Compared with ele. 393
6903	*T Sagittarii*	Max.	4582	Oct. 19	3	+46	9	7.38	0.62	1.85	16	Last interval 408 days
6905	*R Sagittarii*	Min.	4504	Aug. 2	44	+12	4	–	–	–	–	
6923	*Z Sagittarii*	Max.	4492.7	July 21	8	+11	9	7.56	0.96	0.94	20	

Individual Observations.

Including Observations by ARTHUR C. PERRY.

5644 *Z Librae.*

(Continued from 333.)

Julian	Calendar	Mag.
	1898	
4423.6	May 13	11]
4424.7	14	11.4]
4450.6	June 9	11.4]
4450.6	9	10.7]p
4458.6	17	11.2
4461.6	20	11.03_2
4462.6	21	11.0p
4465.6	24	11.13_2
4477.6	July 6	10.7:p
4478.6	7	11.36_2
4486.6	15	11.08

5770 *R Herculis.*

(Continued from 421.)

Julian	Calendar	Mag.
	1898	
4458.6	June 17	11.0
4462.6	21	11.69_2
4463.6	22	10.69_2
4464.6	23	11.19_2
4465.6	24	10.77_2
4476.6	July 5	9.59_2
4484.6	13	8.38_4
4489.6	18	8.88_2
4495.6	24	8.04_2
4500.6	29	8.13_2
4506.6	Aug. 4	8.80_2
4515.6	13	8.65_2
4517.5	15	8.57
4533.5	31	9.35_2

5831 *S Scorpii.*

(Continued from 421.)

Julian	Calendar	Mag.
	1898	
4419.6	May 9	12.1
4423.7	13	12.1
4424.7	14	11.4
4427.7	17	11.4
4458.6	June 17	11.3
4462.7	21	11.52_2
4465.6	24	11.47_2
4480.6	July 9	12.28_2

5860 *U Scorpii.*

Julian	Calendar	Mag.
	1896	
3711.6	May 31	13]
3743.6	July 2	13]
	1897	
4097.7	June 21	13]
4163.6	Aug. 26	13]
	1898	
4458.6	June 17	13]

5887 *V Ophiuchi.*

(Continued from 421.)

Julian	Calendar	Mag.
	1898	
4427.6	May 17	7.8p
4446.6	June 5	8.2p
4458.6	17	8.5p
4464.6	23	8.7p

5931 *S Ophiuchi.*

(Continued from 388.)

Julian	Calendar	Mag.
	1898	
4450.6	June 9	10.3p
4458.6	17	10.0 :
4462.6	21	11.00_2
4462.6	21	10.7p
4463.6	22	10.44_2
4464.6	23	10.67_2
4465.6	24	10.68_2
4477.6	July 6	11.4p
4487.6	16	11.7]p

6044 *S Herculis.*

Cont. from 421. Comp. Stars 388)

Julian	Calendar	Mag.
	1898	
4423.6	May 13	11.3
4458.6	June 17	12.3
4478.6	July 7	12.3
4487.6	16	12.0
4504.6	Aug. 2	11.3

6132 *R Ophiuchi.*

(Continued from 388.)

Julian	Calendar	Mag.
	1898	
4450.6	June 9	11.5]
4458.6	17	12.5]
4481.6	July 10	13]
4517.6	Aug. 15	9.5

6160 *RT Herculis.*

(Continued from 421.)

Julian	Calendar	Mag.
	1898	
4423.6	May 13	9.6
4428.6	18	9.8
4456.6	June 15	10.6

6207 *Z Ophiuchi.*

(Cont from 421. Comp. Stars 333)

Julian	Calendar	Mag.
	1898	
4458.6	June 17	11.1
4463.6	22	11.22_2
4478.6	July 7	11.6
4481.6	10	11.54_2
4506.6	Aug. 4	12.1
4507.6	5	12.38_2
4515.6	13 to	
4595.5	Nov. 1	13]
	7 dates	

6225 *RS Herculis.*

Julian	Calendar	Mag.
	1898	
4458.6	June 17	8.0p
4464.6	23	8.1p
4481.6	July 10	8.5p
4507.6	Aug. 5	10.3p
4547.6	Sept. 14	11.0]
4573.5	Oct. 10	11.0]
4597.5	Nov. 3	11.0
4606.5	12	10.92_2

6512 *T Herculis.*

(Continued from 421.)

Julian	Calendar	Mag.
	1898	
4427.6	May 17	9.3p
4446.6	June 5	8.0p
4458.6	17	7.9p
4464.6	23	7.9p
4477.6	July 6	8.3p
4487.6	16	8.8p
4590.5	Oct. 27	9.39_2
4596.5	Nov. 2	8.53_2
4600.5	6	8.97_2
4601.5	7	8.79_2
4608.5	14	8.23_2
4614.5	20	8.30_2

6512 *T Herculis.* — Cont.

Julian	Calendar	Mag.
	1898	
4615.5	Nov. 21	7.93_2
4619.5	25	7.41_2
4624.5	30	7.27_2
4626.5	Dec. 2	7.09_2
4630.5	6	7.32_2
4632.5	8	7.45_2
4637.5	13	7.55_2

6624 *T Serpentis.*

Julian	Calendar	Mag.
	1898	
4451.5	Sept. 18	10.9
4552.5	19	10.59_2
4569.5	Oct. 6	9.92_2
4575.5	12	9.40_2
4583.5	20	9.85_2
4586.5	23	10.00_2
4595.5	Nov. 1	10.05_2
4601.5	7	10.02_2

6849 *R Aquilae.*

(Continued from 421.)

Julian	Calendar	Mag.
	1898	
4458.6	June 17	9.6
4464.6	23	9.83_2
4481.7	July 10	10.3
4484.6	13	10.88
4506.6	Aug. 4	11.3
4507.6	5	11.51_2
4515.6	13	11.65_2
4538.5	Sept. 5	11.73_2
4549.5	Sept. 16	11.42
4560.5	27	11.16
4570.5	Oct. 7	10.85_2

6871 *V Lyrae.*

(Cont. from 421. Comp. Stars 393)

Julian	Calendar	Mag.
	1898	
4550.5	Sept. 17	9.9
4551.5	18	10.20_2
4569.5	Oct. 6	10.01_2
4575.5	12	9.66_2
4583.5	20	9.86_2
4586.5	23	10.07_2
4596.5	Nov. 2	10.41_2

6871 *V Lyrae.* — Cont.

Julian	Calendar	Mag.
	1898	
4606.5	Nov. 12	10.00_2
4614.5	20	10.78_2

6888 *RW Sagittarii.*

(Continued from 425.)

Julian	Calendar	Mag.
	1898	
4443.7	June 2	10.1
4478.6	July 7	10.1p
4550.5	Sept. 17	9.5
4576.5	Oct. 13	9.4
4596.5	Nov. 2	9.23
4605.5	11	9.19

6892 *RX Sagittarii.*

(Continued from 425.)

Julian	Calendar	Mag.
	1898	
4443.7	June 2 to	
4605.5	Nov. 11	12]
	4 dates.	
4478.6	July 7	12]p

6894 *S Lyrae.*

(Cont. from 421. Comp. Stars 339)

Julian	Calendar	Mag.
	1897	
4224.5	Oct. 26 to	
4283.5	Dec. 24	12.5]
	5 dates.	
	1898	
4538.6	Sept. 5	12.5]
4573.5	Oct. 10	12.5]
4601.5	Nov. 7	12.5]

6900 *W Aquilae.*

(Cont. from 421. Comp. Stars 339)

Julian	Calendar	Mag.
	1898	
4542.5	Sept. 9	11.6]
4551.5	18	11.6
4569.5	Oct. 6	10.85_2
4573.5	10	10.66
4579.5	16	10.39_2
4585.6	22	10.17
4590.5	27	10.20_2
4596.5	Nov. 2	10.73_2
4601.5	7	10.79_2
4608.5	14	10.55_2

6903 *T Sagittarii*.

(Continued from 425.)

Julian	Calendar 1898	Mag.
4443.7	June 2	10]
4481.6	July 10	11.0
4481.6	10	11.0P
4495.6	24	10.0
4507.6	Aug. 5	10.0P
4533.6	31	9.54_2
4539.5	Sept. 6	9.35_2
4549.5	Sept. 16	8.97_2
4560.5	27	8.80_2
4564.5	Oct. 1	8.11_2
4572.5	9	7.74_2
4575.5	12	8.01_2
4580.5	17	7.36_2
4583.5	20	7.10_2
4586.5	23	7.53_2
4590.5	Oct. 27	7.63_2
4596.5	Nov. 2	7.33_2
4601.5	7	7.67_2

6905 *R Sagittarii*.

(Continued from 425.)

Julian	Calendar 1898	Mag.
4464.6	June 23	12.1
4465.7	24	11.72_2
4481.6	July 10	12.14_2
4515.6	Aug. 13	12.8]
4538.6	Sept. 5	12.1
4539.5	6	11.66_2

6923 *Z Sagittarii*.

Cont. from 393 Comp Stars 311

Julian	Calendar 1898	Mag.
4464.6	June 23	8.54_2
4465.7	24	8.56_2
4470.6	29	8.17_2
4476.6	July 5	8.13_2
4480.6	9	8.09_2
4487.6	16	7.92_2
4491.6	20	7.56_2
4495.6	24	7.62_2
4500.6	29	7.81_2
4506.6	Aug. 4	8.60_2
4515.6	13	8.46

COMPARISON-STARS, 1893–1898.

5887 *V Ophiuchi*.

Star	DM.	Mag.	n
E	−11°4129	7.39	12
K	−11°4135	8.26	5
L	−11°4154	8.15	5
N	−11°4140	8.53	26
P	−11°4132	8.93	15
1*P*	−11°4151	9.15	3
T	−11°4134	9.27	13
2*T*	−12°4508	9.35	1
U	−11°4138	9.31	17
1*W*	−11°4143	10.82	1
X	−11°4139	10.10	8
1*X*	−11°4142	10.81	1
Z	−11°4137	11.01	3

5830 *R Scorpii*.

Star	DM.	Mag.	n
N	−22°4133	8.16	5
S	−22°4149	9.37	2
U	−22°4139	9.89	17
1*U*	−22°4144	9.79	13
2*U*	−22°4146	9.56	11
3*U*	−22°4147	10.02	2
4*U*	−22°4145	9.32	3
Y	−22°4150	10.64	2
2*Y*	−22°4134	10.50	9
e	5*n*5*f* 4*U*	10.89	4
h	9*f* 2*Y*	11.96	6
i	6*s*5*f* 1*U*	11.55	17
k	4*s*5*p* 4*U*	12.06	2

6512 *T Herculis*.

Star	DM.	Mag.	n
1*E*	+30°3138	5.79	10
G	+30°3133	6.74	17
1*I*	+30°3142	7.26	24
K	+29°3187	6.81	9
R	+30°3127	8.23	29
T	+31°3166	8.41	28
W	+30°3126	9.11	22
Y	+30°3136	9.75	14
Z	+30°3135	10.55	6
1*Z*	+31°3185	10.33	7
2*Z*	+30°3139	9.14	13
3*Z*	+31°3171	10.08	6
k	1*n*2*f* 1*Z*	12.36	7

6849 *R Aquilae*.

Star	DM.	Mag.	n
C	+8°3951	5.67	18
D	+6°1014	6.13	11
1*D*	+5°4035	6.33	11
2*D*	+6°4026	6.52	14
E	+6°4023	6.63	13
2*E*	+6°4021	6.04	12
M	+8°3960	7.80	15
1*M*	+8°3958	7.94	16
T	+8°3961	8.51	14
Z	+8°3968	10.41	32
d	6*n*2*p* *V*	10.64	15
e	6*f* *V*	11.01	19
–	2*np* *V*	11.20	16

MAXIMA AND MINIMA OF LONG-PERIOD VARIABLES,

BY J. A. PARKHURST.

My observations of variable stars between 1898 June 20 and Aug. 26 were made with the 12-inch Brashear refractor of the Yerkes Observatory. I took this opportunity to compare the limit of vision of 6 inches aperture on the 12-inch, with that of my own instrument, a 6.2-inch reflector. I found that 6 inches aperture on the refractor would show stars about $0^{M}.2$ fainter than the limit of the reflector. If $13^{M}.0$ be assumed as the limit of the refractor, my previous estimate of the limit of the reflector, $12^{M}.8$, is exactly confirmed.

While the change in instruments undoubtedly affected the magnitude estimates of the variables, it does not seem probable that the times of maxima and minima were affected, except in one case, which will be mentioned in its proper place.

I wish here to express my thanks to Prof. GEORGE E. HALE, Director of the Yerkes Observatory, for his kindness in allowing me the use of the 12-inch during the summer, also to Prof. E. E. BARNARD for occasional magnitude estimates and micrometric measures of faint variables with the 10-inch refractor.

267. *V Andromedae.*

After the minimum reported in *A.J.* 434, this star rose rapidly during 1898 February and March, and more slowly the first half of April. When last seen in the evening, April 15, it was $8^{M}.4$. It was next seen June 27, at $11^{M}.7$. A comparison with the curve for 1897 would indicate a maximum about April 15, at $8^{M}.4$. It was followed with the 12-inch during July and August, from $11^{M}.7$ down to $13^{M}.9$ August 17, the last observation before the minimum It was invisible (below $12^{M}.5$) with the 6.2-in. reflector. Oct. 11, and rose from $11^{M}.5$ to $10^{M}.5$ from Nov. 2 to 19. The minimum was probably passed about Sept. 1, at a little below 14^{M}.

The interval between my two observed maxima is 263 days; between the two minima, 267 days. Prof. BARNARD measured the position of the variable from the neighboring $11^{M}.5$ star, getting

Position-angle, 249°.1; distance, 207″.96.

294. *W Cassiopeae.*

After the maximum reported in *A.J.* 434, this variable fell slowly to a minimum 1898 April 6, $12^{M}.0$, then rose a little more rapidly to $8^{M}.9$ Aug. 20. I have 14 observations between Jan. 23 and Aug. 20. The intense redness of this star is shown by the fact that its photographic brightness Nov. 11 was $10^{M}.6$, while its visual brightness was $8^{M}.5$.

2376. *S Lyncis.*

I have 25 observations of this star between 1898 Jan. 16 and Oct. 5. It fell steadily from $10^M.0$ at the first observation to $12^M.0$ April 1. After this the 6.2-inch reflector did not suffice to distinguish it from its companion ($12^M.4$, position-angle 158°, distance 12″.5). Prof. BARNARD kindly made 6 observations with the 40-inch, finding a fall from $12^M.4$ March 16 to $12^M.8$ April 8. After the minimum it was first seen July 6 with the 12-inch, at $11^M.8$. It then rose quite rapidly to $9^M.8$ Aug. 15 and $9^M.5$ Oct. 5. An inspection of the light-curve suggests a minimum rather fainter than 13^M, about 1898 June 1.

Prof. BARNARD measured the position of the variable relative to DM. +58°960 (Krueger, Hels-Gotha, *Ast. Gesell. Catal.*) getting position-angle 120°.85, distance 198″.05 ($\Delta\alpha = 21^s.60$, $\Delta\delta = 101''.56$). The position of the variable is therefore

R.A. $6^h\ 32^m\ 2^s.77$	Decl. $+58°\ 2'\ 43''.3$	(1855)
$35\ 56.47$	$0\ 31.3$	(1900)

4315. *R Comae.*

This star was first seen, perhaps, June 14, at $11^M.7$, with the 12-inch, though on this date the identification was doubtful. It was certainly seen July 5 at $11^M.4$, and then rose rapidly to a maximum, about $8^M.2$, 1898 Aug. 6. The fall was then half as fast as the rise, till when last seen in the evening, Sept. 2, it was $8^M.8$. One morning observation, Nov. 14, made it $11^M.4$, so that the rapidity of the decline had been checked still more. I have 9 observations this season.

4471. *T Canum Venaticorum.*

After the maximum reported in *A.J.* 441, the star fell slowly from $9^M.1$, 1898 April 14, to a minimum, $11^M.6$, July 6, then rose at about the same rate, to $9^M.2$ at the last evening observation, Oct. 8. The star appeared $0^M.3$ brighter in the 12-inch than in the 6.2-inch, and, as the observations with the 12-inch were all on the ascending branch of the curve, if allowance were not made for this difference the time of minimum would be 10 days earlier.

6100. *RV Herculis.*

This star has been followed without interruption since the maximum of 1898 March 12, reported in *A.J.* 441. It fell rapidly from $11^M.1$ April 11 to $12^M.6$ May 7, the last observation with the 6.2-inch before minimum. It was invisible June 13 in the 12-inch and with 20 inches of the 24-inch Ritchey reflector; therefore fainter than 14^M. It was seen June 21 with the 40-inch, being equal to the faintest of three small stars 2′ north following. Prof. BARNARD estimated it as about 15^M. It was again seen July 7 with the 40-inch, 3 or 4 steps brighter than the star mentioned. It then rose very quickly and was seen with the 12-inch July 23, at $13^M.5$, and thence followed to $10^M.9$ Aug. 24, the last observation with the 12-inch. The curve shows a minimum within 5 days of June 24, at 15^M or a little below. The following maximum, Sept. 28, at $9^M.75$, was observed with the 6.2-inch, the magnitude being $12^M.2$ at the last comparison, Nov. 19. I have 24 observations between the above mentioned dates. Prof. BARNARD measured with the 40-inch the position of the variable referred to the nearest 12^M comparison star, as follows:

Position-angle, 337°.1; distance, 169″.60, 2 nights.

The interval between my two observed minima is 205 days, between the two maxima, 200 days.

6549. *W Lyrae.*

I have 24 observations since the minimum reported in *A.J.* 434. The succeeding maximum was well marked, 1898 May 6, at $7^M.6$, followed by a well defined minimum, Aug. 8, at $11^M.6$. The intervals between three successive minima have been 194 and 191 days; between two maxima 195 days.

6894. *S Lyrae.*

I have 35 observations of this star between 1896 Oct. 7 and 1898 Nov. 15. The variable was invisible till 1896 Dec. 23, when it was seen at $12^M.3$, and 1897 Jan. 9 was found at $10^M.6$. No more observations were obtained till May 25, when it was found at $11^M.3$ on the descending branch of the curve, and followed to $12^M.8$ Sept. 22. The maximum may have occurred about 1897 March 1. The star was below the limit of the 6.2-inch reflector from 1897 Sept. 22 to 1898 February. It was below $12^M.4$ Feb. 15, and seen at $12^M.0$ March 2. It then rose gradually to a maximum, $10^M.3$, about 1898 May 6, and fell slowly to $12^M.8$ when last seen, Nov. 1. The first maximum was not well determined, but the intervals between corresponding points in the curves give 427 days as an approximation to the period. The nearest stars for identification are, $12^M.8$ foll. 2^s; $11^M.9$ foll. 5^s, 1′.3 S; $11^M.9$ foll. 9^s, 0′.6 S.

6899. *U Draconis.*

In continuation of the observations reported in *A.J.* 433 I have followed this star continuously since 1898 Jan. 4. It fell slowly from $9^M.9$ at the first comparison, to a minimum, $12^M.7$, May 16, then rose a little more rapidly to a maximum, $9^M.0$, Oct. 10, then fell to $9^M.6$ at the last comparison, Nov. 16. I have 30 observations in all. Stars for identification are: $10^M.6$ pr. 14^s, 1′.4 N; $11^M.9$ foll. 14^s, 1′.3 S; $12^M.0$ pr. 34^s, 2′.4 N; $12^M.6$ pr. 18^s, 0′.4 S. (In the place of this star given in *A.J.* 433, for Decl. +67° 2′ 4″ read +67° 2′.4.)

7379. *ST Cygni.*

I have 25 observations of this star between 1898 Jan. 26 and Nov. 1. It was first certainly seen Feb. 15, at $12^M.7$, and rose steadily to a maximum, $9^M.5$, June 16, or possibly 10 days earlier, for the curve was quite flat near maximum. The fall was more rapid than the rise, reaching $12^M.8$ at the last observation. The positions of the following comparison stars from the variable were carefully estimated with the 12-inch, power 275: $12^M.6$ foll. 2^s, $1'.8$ N; $12^M.8$ pr. 5^s, $1'.1$ N; $13^M.0$ pr. 14^s, $1'.0$ S; $13^M.3$ pr. 5^s, $2'.0$ N; $13^M.6$ pr. 7^s, $1'.0$ N; $14^M.0$ pr. 9^s, $0'.1$ N.

8324. *V Cassiopeae.*

My watch on this star has been continuous, and since the minimum reported in *A.J.* 434 I have 27 observations between 1898 March 4 and Nov. 19, yielding a maximum, $7^M.7$, May 4, and a minimum, $12^M.2$, Aug. 26. The light curve presents the usual features, and the correction to my elements (*A.J.* 358) is +3 days for the maximum and −3 days for the minimum.

Marengo, Ill., 1898 *Nov.* 26.

NEW VARIABLE STAR (S.DM. 4°5381),

(1855.0 $21^h\ 3^m\ 22^s.7$ $-4°\ 37'.4$)

By E. E. BARNARD.

On Nov. 7, 1898, I was unable to find any star near the place of this object that would answer to the magnitude assigned it in S.DM., $9^M.8$. A star of $11\frac{1}{2}^M$ or 12^M seemed to occupy its place and upon measurement was found to be closely in the position of the star sought. It was at once concluded the star must be variable, and later observations have fully confirmed its variability. At the observations on Nov. 7, the star must have been near its minimum, for it has since risen at least two magnitudes. The period is probably a long one. Sickness has prevented any observations of it for some time.

On Nov. 7, it was micrometrically compared with S.DM. 4°5380, of $9^M.7$:

$$\Delta\alpha = 0'\ 54''.4 = 0^m\ 3^s.64 \quad \text{(1 setting of wires)}$$
$$\Delta\delta = 4\ 28.2 \quad \text{(1 setting of wires)}$$

The variable being north following.

Three other small stars were at the same time compared with 5380; these I will call *b*, *c*, *d*, and as they may be useful hereafter, I will give the measures:

$$b,\ 12^M\ ,\ \Delta\alpha = 1'\ 5''.97\ (2) \qquad \Delta\delta = 1'\ 52''.15\ (2)$$
$$c,\ 13\ \ ,\ \Delta\alpha = 1\ 58.38\ (2) \qquad \Delta\delta = 2\ 39.28\ (2)$$
$$d,\ 11.8\ ,\ \Delta\alpha = 2\ 35.38\ (2) \qquad \Delta\delta = 0\ 35.37\ (2)$$

All three stars follow 5380, and are north of it. What was supposed to be a nebula was also measured:

$$\Delta\alpha = 1'\ 29''.01\ (2) \qquad \Delta\delta = 2'\ 53''.31\ (1)$$

north following 5380. This was afterwards found to be two small stars close together.

On Nov. 7, the variable and *d* were exactly equal. By Nov. 15, it had gained about $\frac{1}{2}^M$. On Nov. 23, it was about $0^M.2$ less than 5380. It had still slowly brightened up to Dec. 8, when it was about $9^M.7$, but still slightly less than 5380.

I am under the greatest obligation to Professor E. C. PICKERING, who has kindly supplied me with measures of the photographic magnitudes of this star obtained from the photographs taken at the Harvard College Observatory since 1890, and which I have received since writing the foregoing portion of this note. This gives an almost complete record of the light-changes of the star during the past eight years and up to within five days of the time of its discovery. I append the list of measures which he has kindly had made for me. Professor PICKERING says these measures seem to show that the star's period is about 150 days.

PHOTOGRAPHIC MAGNITUDES.

Date	Mag.	Date	Mag.
1890 June 27	<11.8	1895 Sept. 3	<11.4
1891 May 21	10.20	" " 3	< 9.4
" " 22	10.46	1896 May 22	<11.8
" Sept. 2	<10.8	" Aug. 25	10.38
" Oct. 2	<10.8	" Oct. 7	10.64
" Nov. 2	10.71	" " 9	10.81
1892 April 6	<10.4	" Nov. 13	11.66
" " 7	<10.4	1897 Sept. 14	11.44
" " 7	<11.1	" " 15	11.40
" Sept. 2	10.93	" Oct. 29	10.59
" " 26	<11.5	" Nov. 10	10.36
" Oct. 6	11.58	1898 Aug. 20	<12.1
" " 11	<11.8	" Sept. 5	<11.6
1893 July 20	11.46?	" " 5	<11.1
" " 23	<11.6	" " 6	<10.9
" Aug. 1	11.45	" " 6	<11.3
" " 30	10.93	" " 6	<12.1
" Sept. 13	10.59	" " 9	<11.6
" Oct. 5	10.28	" " 13	<10.8
" " 7	10.03	" " 29	<10.9
" " 31	10.64	" Oct. 25	11.02?
1894 May 21	10.54	" Nov. 1	11.84
" Sept. 24	<10.8	" " 2	11.84
1895 June 8	10.88		

Mr. J. A. PARKHURST has sent me his observations of this star which he kindly made at my request, as follows:

	M		M
1898 Dec. 3	10.1	1898 Dec. 22	10.2
7	10.2	28	10.0
9	10.2	1899 Jan. 2	10.1
15	10.3	7	9.9
17	10.2	14	9.8

Williams Bay, Wis., 1898 *Dec.* 26.

OBSERVATIONS OF COMETS f 1898 AND i 1898,

MADE WITH THE 18-INCH EQUATORIAL OF THE FLOWER OBSERVATORY, UNIVERSITY OF PENNSYLVANIA,

By HENRY B. EVANS.

1898 Greenwich M.T.	*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			Comet f 1898.					
			m s	′ ″	h m s	° ′ ″		
Sept. 21 20 45 28	1	4	. . .	−3 11.3	. . . .	+ 6 31 8.0	. . .	0.701
27 20 34 59	2	8	+1 6.58	−0 43.0	6 34 14.23	+ 4 41 6.9	n9.445	0.717
Oct. 12 21 21 17	3	4 , 5	−3 18.36	+5 28.8	6 53 18.08	− 0 7 49.5	n9.101	0.756
12 21 21 17	4	5 , 7	−3 53.77	+2 31.6	6 53 18.83	− 0 8 0.0	. . .	. .
			Comet i 1898.					
Nov. 6 12 11 0	5	7 , 8	+1 34.43	+1 45.5	17 38 25.63	+16 20 48.7	9.647	0.682
7 11 58 18	6	7 , 8	+2 7.59	+0 25.0	17 41 48.33	+14 27 42.0	9.633	0.686

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	6 21 45.96	+3.26	+ 6 34 12.6	+6.7	Weisse's Bessel No. 576
2	6 33 1.30	+3.35	+ 4 41 12.6	+6.3	Boss, Albany A.G. Cat. No. 2312
3	6 56 32.91	+3.53	− 0 13 23.2	+4.9	Weisse's Bessel No. 1680
4	6 57 9.07	+3.53	− 0 10 36.4	+4.8	Weisse's Bessel No. 1696
5	17 36 49.17	+2.03	+16 18 58.6	+4.6	Auwers, Berlin A.G. Cat. No. 6389
6	17 39 38.64	+2.10	+14 27 12.5	+4.5	Weisse's Bessel No. 744

OBSERVATION OF ASTEROIDS,

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

By F. E. ROSS.

Mt. Hamilton M.T.	*	No. Comp.	Planet — * $\Delta\alpha$	Planet — * $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			(148) *Gallia.*					
1898 h m s			m s	′ ″	h m s	° ′ ″		
Aug. 19 11 4 52	1	11 , 8	−1 52.05	+5 14.7	21 49 36.66	−13 44 28.8	n8.996	0.837
20 10 35 34	2	10 , 8	+1 2.42	+1 50.1	48 51.14	−13 59 43.3	n8.192	0.832
24 11 29 29	3	6 , 7	+4 4.01	−3 35.0	45 45.05	−15 2 18.4	n8.015	0.845
25 11 23 59	4	10 , 10	+3 18.09	−8 46.6	45 0.11	−15 17 40.5	n7.649	0.846
26 10 22 13	5	11 , 10	+0 33.53	+3 1.5	44 16.73	−15 32 21.1	n9.103	0.844
26 13 39 31	5	11 , 12	+0 27.25	+0 56.0	44 10.45	−15 34 26.6	9.438	0.826
30 12 1 18	6	10 , 10	−0 12.55	+1 25.5	41 16.85	−16 33 38.6	8.911	0.849
31 9 56 9	7	8 , 7	+1 34.81	+4 0.9	40 38.05	−16 47 5.4	n9.123	0.849
Sept. 4 9 37 31	9	8 , 8	−0 3.72	+6 15.6	37 54.90	−17 44 32.2	n9.128	0.854
4 14 17 29	10	8 , 8	+1 23.79	−6 25.1	37 46.78	−17 47 19.6	9.605	0.801
9 9 32 12	11	8 , 8	+0 16.33	+0 36.3	34 51.67	−18 52 36.0	n8.993	0.863
11 10 10 31	12	8 , 8	−1 13.15	+2 22.1	33 45.37	−19 18 45.0	7.627	0.867
12 10 23 26	13	8 , 8	−0 40.22	+8 47.8	21 33 13.87	−19 31 26.2	9.628	0.868
			(19) *Fortuna.*					
Sept. 9 10 5 44	14	8 , 8	−0 10.39	+3 49.9	1 6 46.79	+ 8 28 51.7	n9.595	0.680
11 11 23 49	14	8 , 8	−1 3.63	−2 49.6	5 53.60	+ 8 22 12.5	n9.425	0.647
19 14 1 56	15	8 , 8	−0 5.58	−1 18.3	1 18.15	+ 7 48 54.2	9.076	0.640
19 14 19 8	16	8 , 8	−0 11.25	+2 33.5	1 17.46	+ 7 48 3.5	9.186	0.642
20 15 25 33	17	8 , 8	+0 25.40	−4 49 8	1 0 35.23	+ 7 42 49.1	9 451	0.756
28 11 7 28	18	8 , 8	−0 50.58	+3 26.3	0 54 44.43	+ 6 59 10.5	n9.188	0.655
Oct. 3 10 31 58	20	8 , 8	+0 32.13	+9 40.0	50 38.78	+ 6 28 14.0	n9.243	0.660
12 8 30 24	21	8 , 8	+2 18.25	−1 47.4	0 43 12.58	+ 5 30 30.4	n9.495	0.682
			1898 (*DR*).					
Nov. 12 10 32 32	22	8 , 8	+2 48.28	−3 46.9	23 34 15.42	−16 39 59.5	9.470	0.828
13 9 42 12	23	9 , 8	−0 34.29	+2 13.6	34 55.47	−16 41 55.3	9.320	0.842
18 7 24 37	27	8 , 9	−0 0.07	+6 35.4	38 39.94	−16 46 50.7	n8.652	0.853
Dec. 1 7 22 12	28	8 , 10	−0 30.61	+2 18.4	51 15.32	−16 24 14.0	8.509	0.852
2 6 21 5	30	10 , 9	−6 6.63	+1 1.8	23 52 19.25	−16 20 48.2	n8.963	0.849

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 51 24.16	+4.55	−13 50 5.5	+22.0	Weisse's Bessel, 21h1146
2	21 47 44.13	+4.59	−14 1 55.2	+21.8	American Ephemeris
3	21 41 36.43	+4.61	−14 59 4.8	+21.4	½ (Munich I 29481 + Weiss's Arg. 21638)
4	21 41 37.40	+4.62	−15 9 15.3	+21.4	Weiss's Argelander 21639
5	21 43 38.56	+4.64	−15 35 41.2	+21.6	½ (Munich I 29572 + Weisse's Bessel 985)
6	21 41 24.70	+4.71	−16 35 25.1	+21.1	Auwers's Fund. Cat.
7	21 38 58.54	+4.70	−16 51 27.3	+21.0	Compared with *8
8	21 39 5.74	+4.70	−16 59 37.9	+21.0	Munich I 11942
9	21 37 53.92	+4.70	−17 51 8.4	+20.6	½ (Munich 29289 + Weiss's Arg. 16987)
10	21 36 18.29	+4.70	−17 41 15.0	+20.5	Dunsink 902
11	21 34 30.61	+4.73	−18 53 32.5	+20.2	Cordoba Gen. Cat. 29658
12	21 34 53.78	+4.74	−19 21 27.1	+20.0	Cordoba Gen. Cat. 29662
13	21 33 49.35	+4.74	−19 40 33.8	+19.8	Weiss's Argelander 16946
14	1 6 52.88	{ +4.30 { +4.35	+ 8 24 34.7	{ +27.1 { +27.1	Weisse's Bessel 1h53
15	1 1 19.29	+4.44	+ 7 48 55.5	+28.3	⅓ (Glasgow 270 + Paris 1428 + Yarnall 584)
16	1 1 24.27	+4.44	+ 7 45 1.8	+28.3	Argelander +7°168
17	1 0 5.37	+4.46	+ 7 47 10.5	+28.4	Paris 1394
18	0 55 30.45	+4.56	+ 6 55 11.9	+29.3	DM. +6°143; compared with *19
19	0 55 12.75	+4.56	+ 6 18 11.0	+29.3	Paris 1301
20	0 50 2.07	+4.58	+ 6 18 4.5	+29.5	Paris 1167
21	0 40 49.71	+4.62	+ 5 31 47.7	+30.1	Weisse's Bessel 0h666
22	23 31 22.77	+4.37	−16 36 35.7	+23.4	Weiss's Argelander 18024
23	23 35 25.38	+4.38	−16 44 32.0	+23.1	11M compared with *24
24	23 36 48.52	+4.38	−16 49 50.7	+23.1	DM. −17°6799; compared with *'s 25 and 26
25	23 43 25.44	. .	−16 50 10.4	. .	Weiss's Argelander 18116
26	23 43 51.50	. .	−16 49 39.8	. .	Weiss's Argelander 18120
27	23 38 35.65	+4.36	−16 53 49.0	+22.9	DM. −17°6806; compared with *'s 25 and 26
28	23 51 41.67	+4.26	−16 26 54.4	+22.0	10M.5 compared with *29
29	23 53 6.18	+4.26	−16 24 51.1	+22.0	Weiss's Argelander 18190
30	23 52 21.63	+4.25	−16 22 11.9	+21.9	Compared with *29

Mount Hamilton, 1898 *December* 16.

ELEMENTS OF COMET *b* 1898,

BY HEBER D. CURTIS.

From twenty-four observations by C. D. PERRINE, and two by J. CISCATO and A. ANTONIAZZI, the following normal places were formed:

1898.0 G.M.T.	α	δ	p
	h m s	° ′ ″	
March 22.0	21 25 18.47	+18 46 28.2	7
April 28.0	0 18 1.97	+49 13 47.1	7
June 6.0	3 31 35.99	+56 17 15.9	6
July 19.0	5 34 7.35	+53 31 34.1	6

From these the following elements were computed:

Epoch, March 20.0, 1898.0 G.M.T.

$$M = 0°\ 0'\ 25''.4$$
$$\left.\begin{aligned}\omega &= 47\ 18\ 20.2\\ \Omega &= 262\ 26\ 3.6\\ i &= 72\ 31\ 55.8\end{aligned}\right\}1898.0$$
$$\varphi = 78\ 29\ 56.2$$

$$\log a = 1.736718$$
$$\log q = 0.039459$$
$$\log e = 9.991191$$
$$\log \mu = 0.944929$$

Perihelion passage, 1898 March 17.11895, G.M.T.
Period, 402.789 years.

C − O

$$\Delta\lambda' = +0''.2 \qquad \Delta\beta' = +2''.3$$
$$\Delta\lambda'' = 0.0 \qquad \Delta\beta'' = -1.4$$

CONSTANTS FOR THE EQUATOR OF 1898.0.

$$x = r[9.512398]\sin(23°\ 26'\ 14.2 + v)$$
$$y = r[9.999996]\sin(292\ 43\ 47.5 + v)$$
$$z = r[9.975703]\sin(22\ 38\ 46.0 + v)$$

OBSERVATIONS OF *EROS*,

MADE AT THE U.S. NAVAL OBSERVATORY, WASHINGTON, D.C.,

By Prof. STIMSON J. BROWN, U.S.N.

[Communicated by Prof. Wm. Harkness, U.S.N., Astronomical Director.]

Washington M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's Apparent α	Planet's Apparent δ	log pΔ for α	log pΔ for δ
1898 h m			m s	′ ″	h m s	° ′ ″		
Sept. 11 9 29.9	1	8 , 5	+0 14.96	−2 10.1	20 43 37.98	−6 20 35.5	8.3383	0.7962
12 8 44.0	2	8 , 5	−0 4.61	+2 45.74	20 42 45.65	−6 20 47.8	n8.8313	0.7956
13 9 15.6	3	8 , 5	+0 33.25	−0 8.12	20 41 53.16	−6 21 0.1	8.0831	0.7981
*Nov. 11 8 40.2	4	8 , 4	−0 26.38	+1 39.55	21 12 44.37	−4 4 32.7	9.4977	0.7687
20 6 22.8	5	8 , 5	+0 6.55	+4 31.04	21 27 7.41	−3 7 18.3	9.0558	0.7695
Dec. 1 6 5.4	6	8 , 5	+0 5.63	+3 59.46	21 46 58.26	−1 41 25.4	9.0868	0.7573
5 6 25.7	7	12 , 6	+2 15.61	+0 30.30	21 54 46.37	−1 5 57.1	9.3255	0.7515
9 6 47.4	8	12 , 5	−0 41.29	−2 36.22	22 2 48.81	−0 28 18.2	9.3615	0.7462
23 6 13.5	9	15 , 5	−1 9.85	−0 43.63	22 32 39.60	+1 59 8.1	9.3325	0.7252
1899 Jan. 1 6 11.2	10	15 , 5	−0 53.41	−2 49.56	22 53 18.13	+3 46 14.4	9.3749	0.7097
2 6 30.2	11	8 , 5	−0 18.28	+4 15.70	22 55 41.62	+3 58 54.3	9.4327	0.7097

The following corrections have been applied to reduce the apparent declination to the epoch of the observed right-ascension.

	″		m			″		m
Nov. 11	−1.0	for	− 4.0		Dec. 9	+ 9.46	for	+23.2
20	−0.44	"	− 1.5		23	− 5.62	"	−11.8
Dec. 5	−6.95	"	−18.35		Jan. 1	−11.22	"	−15.3

* The declination may be *one revolution* of micrometer farther south −4° 4′ 42″.7, owing to wrong reading of revolution scale, the recorded revolution at the beginning and end of the declination measures differing one revolution.

Mean Places for 1898.0 and 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 43 18.70	+4.32	−6 18 43.2	+18.1	Munich II, 10842, Wash. T.C. 4 observations
2	20 42 45.92	+4.31	−6 23 51.6	+18.1	" 10832, " 4 "
3	20 41 15.62	+4.29	−6 21 9.9	+17.9	Bessel 20h997, " 3 "
4	21 13 7.16	+3.59	−4 6 31.4	+20.1	Ll. 41356, " 3 "
5	21 26 57.31	+3.55	−3 12 9.9	+21.0	S.DM. −3°5234 " 1 "
6	21 46 49.13	+3.50	−1 45 47.2	+22.3	¼ (W.B. + 2 Copeland and Börgen + M. II)
7	21 52 27.29	+3.47	−1 6 42.9	+22.5	⅓ (W.B. + C.B. + M. II)
8	22 3 26.64	+3.46	−0 26 14.6	+23.1	¼ (W.B. + C.B. + M. II + Schj.)
9	22 33 45.98	+3.47	+1 59 32.8	+24.5	⅓ (Bonn + M. I + M. II) p.m. = +s.035
10	22 54 11.15	+0.39	+3 49 10.5	+ 4.65	Boss, Albany, A.G. Catal. 7933
11	22 55 59.45	+0.45	+3 54 32.6	+ 6.05	" " " 7943

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SOME POINTS RELATING TO THE SOLAR MOTION AND THE MEAN PARALLAX OF STARS OF DIFFERENT ORDERS OF MAGNITUDE.

By SIMON NEWCOMB.

In this *Journal*, Vol. XVII, p. 41, I published a paper "On the Solar Motion as a Gauge of Stellar Distances." Soon after it appeared I learned that its methods were not new, KAPTEYN having treated the subject from the same point of view in a communication to the Amsterdam Academy in 1893. In some points this author had not only anticipated the methods of my paper, but carried his work farther than I had contemplated doing, especially in investigating the relative proper motions of stars having different types of spectra. More recently, *Astr. Nachr.* Bd. 146, S. 97, he has applied the method to determining the mean parallax of stars of different magnitudes, as a preliminary datum for this, deriving the absolute amount of the solar motion from VOGEL's observations of motions of stars in the line of sight. Under these circumstances it would seem still less necessary that I should continue my unfinished work on the same lines, were it not that the subject is of such breadth and interest that it is not easily exhausted.

I.

The Absolute Speed of the Solar Motion Derived from Observed Parallax of Stars.

It is quite obvious that when we know the parallax of a star, and the apex of the solar motion, the observed proper motion of the star in apical distance will give us the relative linear motion of the star and sun in the direction of the apex. If we know the parallax of a number of stars, we may thus find the solar motion relative to the mean of those stars. On proceeding to collect a list of stellar parallaxes for this purpose I found the number of derived parallaxes which we might fairly consider real to be greater than I had anticipated, numbering about seventy.

The following table gives a list of these parallaxes as derived from all the sources accessible to the writer up to the present time. The three negative ones are, of course, fictitious; they should be taken as indicating that the actual parallax is insensible. The results are only given to 0″.01, because I conceive that in no case would the thousandths of a second have any value. The weaker determinations are marked by one or two colons; but there is necessarily a wide margin for judging when such a mark should be applied. I have included no determinations which there is reason to suppose entirely fictitious.

The columns τ and σ contain the centennial proper motions resolved in the directions of sun-way longitude and apical distance. In the case of the Bradley stars these motions have been most courteously communicated to me by Professor KAPTEYN, with permission to use them. They rest on AUWERS's proper motions. The other stars, nearly all stars of larger proper motion, I have independently resolved with the help of Mrs. E. BROWN DAVIS. For the position of the apex we used

$$A = 277°.5 \quad ; \quad D = +38°$$

while KAPTEYN used 276° and +34°. Hence there is a lack of homogeneity in the results; but this is unimportant in the present work.

The column sin λ gives the sine of the star's distance from the adopted apex.

To derive the speed of the solar motion from these data we put v, this speed, in terms of the earth's distance from the sun, and the year as units.

Then, each parallax that we determine gives an equation of condition,

$$v\,\pi \sin\lambda = \sigma \div 100$$

A vital question now is, what relative weight should we assign to the values of σ for the different stars? We must note that the probable error of a σ is only slightly that of the determination, and mainly that of the general dispersion of the absolute proper motions. Other things equal, these will vary directly as the parallax of the star. The value of τ, being independent of the solar motion, will afford us a rude though uncertain index to this quantity.

When τ is large the star certainly has a large absolute motion, but we cannot assert the converse except as a weak presumption.

Another disturbing element is the uncertainty of π. If the probable error of π be E_π, we shall have a probable error $E_\pi\, v \sin\lambda$ to be combined with the probable dispersion of σ.

Basing my judgement on these considerations, I have assigned to each star a multiplier h depending on τ and the probable error of π, so that when each equation is multiplied by h, each equation may be supposed of the same weight. In general, h is unity; it is diminished below unity according to the amount and number of the unfavorable factors, τ, π and $E\pi$. To free the process from bias I have adopted a system of factors, h, found in the table, depending mainly on the value of $\frac{\tau}{100\pi}$, or the linear motion of the star in sun-way longitude, by the formula

$$h = 1 - \frac{\tau}{100\pi}$$

The factor h was still farther diminished when the parallax was uncertain by an important fraction of its amount.

Parallaxes and Solar-Way Motions of Stars.

Star	For 1900 R.A.	Decl.	π	Proper Motion τ	σ	sin λ	h	v	Wt.
	h m	°	″	″	″				
β Cassiopeae	0 4	+58.6	0.15	− 2	+ 56	0.82	1.0	5	7
Gr. 34	0 13	+43.4	.30	+163	+231	.88	0.9	9	7
ξ Tauri	0 14	−65.5	.06	+169	+116	.85	0.3	23	2
β Hydri	0 20	−77.8	.13	+ 76	+213	.81	0.9	19	6
α Cassiopeae	0 35	+56.0	.04:	− 1	+ 5	.90	0.5	1	4
η Cassiopeae	0 43	+57.2	.20	+ 7	+124	.87	1.0	7	8
γ Cassiopeae	0 50	+60.1	.01:	0	+ 2	.90	0.2	2	2
μ Cassiopeae	1 1	+54.4	.14	+ 19	+372	.90	1.0	28	[8]
Polaris	1 22	+88.8	.06	+ 1	+ 4	.79	1.0	1	6
e Eridani	3 16	−43.5	.14	+121	+288	.60	0.8	34	[3]
50 Persei	4 2	+37.8	.04::	+ 1	+ 24	.98	0.5	6	5
o^2 Eridani	4 11	− 7.8	.18	−392	+ 97	.64	0.5	8	2
α Tauri	4 30	+16.3	.10	− 2	+ 19	.84	1.0	2	7
α Aurigae	5 9	+43.9	.09	− 1	+ 43	.99	1.0	5	10
β Orionis	5 10	− 8.3	.00	+ 1	− 1	.53	0.0	. .	0
α Orionis	5 50	+ 7.4	.02	+ 4	− 1	.67	0.6	− 1	3
β Aurigae	5 52	+44.9	.06:	− 5	0	.98	0.5	0	5
α Argus	6 22	−52.6	.01	. .	. . .	. .	0.0	. .	0
ψ^5 Aurigae	6 39	+43.7	.11	− 2	− 15	.98	1.0	− 1	10
α Can. Maj.	6 41	−16.6	.37	− 28	+128	.31	1.0	12	1
51 H. Cephei	6 53	+87.2	.03:	− 5	+ 4	.82	0.3	2	2
α Geminorum	7 28	+32.1	.20::	− 15	+ 12	.93	0.8	1	7
α Can. min.	7 34	+ 5.5	.30	− 30	+120	.69	1.0	6	5
β Geminorum	7 39	+28.3	.06	− 57	+ 23	.90	0.8	5	6
Ll. 15290	7 45	+31.0	.02	+ 24	+153	0.95	0.1	80	[1]
ι Urs. Maj.	8 52	+48.5	.13:	− 24	+ 43	1.00	0.7	3	7
10 Urs. Maj.	8 54	+42.2	.20	− 22	+ 45	1.00	1.0	2	10
Ll. 18115	9 5	+53.3	.15	−103	+134	0.99	0.9	9	9
θ Urs. Maj.	9 26	+52.2	.07	− 43	+101	1.00	0.9	14	9
Ll. 19022	9 36	+43.4	.06	+ 48	+ 64	1.00	0.7	11	7
20 Leo. min.	9 55	+32.5	.06	− 11	+ 68	1.00	1.0	11	10
α Leonis	10 3	+12.5	.02	− 17	+ 17	0.94	0.8	9	7
Gr. 1618	10 5	+50.0	.18	− 72	+126	.99	0.9	7	9
Gr. 1646	10 22	+49.4	.10	+ 66	+ 58	.98	0.9	6	9
Gr. 1657	10 27	+49.7	.04	+ 9	− 24	.98	0.8	− 6	8
Ll. 20670	10 38	+47.7	− .01	. .	. .	. .	0.0	. .	. .
Ll. 21185	10 58	+36.7	.46	+305	+363	.99	0.9	8	9
Ll. 21258	11 0	+44.1	.22	−357	+259	.98	0.6	12	6
Σ 1516	11 9	+74.0	.15	− 32	+ 31	.86	1.0	2	7
O.A. 11677	11 15	+66.4	.27:	−181	+245	.89	0.7	10	6
Σ 1561	11 33	+45.7	.03	− 43	+ 50	.96	0.5	18	5
Gr. 1822	11 40	+48.3	.02	− 16	+ 67	.94	0.2	35	0
Gr. 1830	11 47	+38.5	.14	+705	+ 20	.96	0.0	1	0
Ll. 22632	11 57	+43.7	−0.04	+ 23	+ 65	0.94	0.0	. .	0

Stars	For 1900 R.A.	Decl.	π	Proper Motion τ	σ	sin λ	h	v	Wt.
	h m	°	"	"	"				
Ll. 22810	12 4	+40.8	0.06	− 13	+ 31	0.94	1.0	5	9
β Comae	13 7	+28.4	.11	−114	+ 28	.91	0.8	3	7
β Centauri	13 56	−59.9	.05	+ 1	+ 4	.92	1.0	1	8
α Bootis	14 11	+19.7	.03	+123	+191	.85	0.0	73	0
α Centauri	14 32	−60.4	.75	−302	+209	.94	1.0	3	9
Ll. 27298	14 53	+54.3	.08	− 47	+100	.64	0.9	20	4
α Scorpii	16 23	−26.2	.02	+ 1	+ 3	.92	0.5	2	4
η Herculis	16 39	+39.1	.40:	+ 9	− 1	.37	0.7	0	0
π Herculis	17 11	+36.9	.11:	0	+ 3	.26	0.5	1	0
δ Herculis	17 11	+24.9	.05:	+ 12	+ 10	.32	0.4	5	0
γ Draconis	17 30	+55.3	.32:	− 16	− 4	.40	0.9	0	2
O.A. 17415	17 37	+68.4	.22	+ 81	−108	.52	0.9	−10	2
70 Ophiuchi	18 0	+ 2.5	.19	+ 41	+105	.52	1.0	10	3
δ Urs. min.	18 5	+86.6	.03:	− 4	+ 5	.75	0.6	2	3
α Lyrae	18 33	+38.7	.11	− 10	+ 36	.13	1.0	26	0
O.A. 18609	18 42	+59.5	.35:	+150	−174	.37	0.9	−13	1
31 Aquilae	19 20	+11.7	.06	+ 95	− 22	.44	0.6	− 7	1
σ Draconis	19 33	+69.5	.26:	−115	−143	.59	0.8	−10	3
α Aquilae	19 46	+ 8.6	.23	+ 67	− 2	.52	1.0	0	3
α Cygni	20 38	+44.9	− .01	+ 1	+ 1	. .	0.0	. .	0
61 Cygni	21 2	+38.2	.39	+357	+379	.52	0.8	19	2
α Cephei	21 16	+62.1	.06:	− 4	+ 15	.63	0.7	4	3
ι Indi	21 55	−57.2	.20	+143	+440	.97	0.9	23	8
α Gruis	22 2	−47.4	.02	− 3	+ 21	0.99	0.5	10	5
α Piscis Austr.	22 52	−30.1	.13	+ 9	+ 34	1.00	1.0	3	10
Lac. 9352	22 59	−36.5	.28	+561	+412	0.99	0.5	15	5
Br. 3077	23 8	+56.6	.15	+ 50	+203	.79	1.0	17	6
85 Pegasi	23 57	+26.5	0.05	− 43:	+124	0.94	0.6	25	2

From the data thus prepared the definitive value of v was derived by three methods.

First method. The equations of condition were written in the form

$$av = n$$

where

$$a = 100\,h\pi \sin\lambda$$
$$n = h\sigma$$

and then a normal equation

$$[aa]\,v = [an]$$

was found. This equation is

$$13640\,v = 79740$$

giving

$$v = 5.85$$

Second method. In the preceding method the result is influenced too much by the stars of large parallax. Hence I formed another quasi-normal equation

$$v\Sigma a = \Sigma n$$

This gave

$$v = 7.2.$$

Third method. This rests on the consideration that the distance of the star should not be a factor in determining the weight of a value of v derived from its motion, provided only that the parallax and proper motion are well determined. We are investigating linear velocity, and our conclusions should, so far as possible, rest on the observed relative linear velocity of the sun and each star. This relative velocity in the direction of the parallactic motion is for each star,

$$v = \frac{\sigma}{100\,\pi \sin\lambda}$$

The values of v from this equation are given in the table. To each value has been assigned a weight

$$w = 10\,h \sin^2\lambda$$

Excluding three stars, each of which gave $v > 25$, the mean result is

$$v = 6.4 = 30 \text{ k.m. per second.}$$

This is the same as the orbital motion of the earth. Its probable error, as derived from the dispersion of the proper motions, would be about a unit or less. But it may be influenced by a systematic tendency arising in this way: — About half the stars in the list, probably forty in all, have been selected for the determination of parallax on account of their large proper motion. For our purpose the selection should be made with impartiality as regards the value and sign of the actual motion away from the apex, say σ_0. When σ_0 is positive, the apparent proper motion is increased by the parallactic motion, while it is

diminished in the opposite case. Hence, in a selection of stars whose apparent proper motion exceeds a certain limit, there will be a tendency to select those for which σ_0 is positive rather than those for which it is negative.

One way in which we can judge whether there has been such a bias in the selection of the stars is by comparing the number of negative and positive values of σ in the case of the parallax stars with the number in the case of stars in general. I find by a partial count of KAPTEYN's values of σ for the Bradley stars that, in the case of absolute values of 20″ or greater, there are about ten positive to one negative. In the preceding list of parallax stars we have

$$44 \text{ values of } \sigma > +19''$$
$$5 \text{ values of } \sigma < -19''$$

This result does not indicate any bias in the case of stars with considerable proper motion. In the case of the remaining stars, mostly investigated in consequence of their brightness, there are fourteen positive values of σ to six negative values, a preponderance which is no greater, I conceive, than we should expect as the result of the parallactic motion. Moreover, in taking the mean value of v, I have thrown out four stars for which $v > 25$, and none on account of a large negative value.

On the other hand, I find for the mean result of twenty-two bright stars, in which there is certainly no bias as to proper motion,

$$v = 3.5 = 16.5 \text{ k.m. per second,}$$

which agrees with KAPTEYN's conclusion from motions in the line of sight, and strengthens the impression of an injurious effect of selection in the case of the stars of large apparent motion.

In this connection the following result may not be devoid of interest. Desiring to see whether the stars of very large apparent proper motion showed any community of motion, I determined the apex and mean parallactic motion from them alone. I took sixteen stars whose annual motion exceeds 2″.6, and *Arcturus*. The result is:

$$A = 276^\circ.3 \quad ; \quad D = +41^\circ.3 \quad ; \quad R = 3''.15$$

The close approach of the position of the apex to the truth shows that the actual motions of these stars take place quite at random. Assuming the motion R to be really, in the general mean, a parallactic motion, we should have, for the mean parallax,

$$\pi = \frac{\sigma}{v} = 0''.50$$

when we assume $v = 6.3$, and a yet greater value if we take a smaller v. The parallaxes of thirteen of the seventeen stars have been actually measured, with the mean result,

$$\pi = 0''.27$$

I conclude that the bias already described greatly affects these stars; in fact that they are mostly stars with a large actual motion in a direction the opposite of the solar motion.

II.

The Most Likely Position of the Solar Apex.

Determinations of the position of the apex have generally been based on stars having a large proper motion. The use of these stars has both an advantage and an objection. The advantage is that such stars are in the general mean, so far as we can determine, the nearest to us. The objection is that they are also stars having, in the general mean, the larger absolute proper motions. The best stars to use would be those nearest us with small proper motion. But we have no way of identifying these stars. I conceive that the advantage and drawback about balance each other, and that it is desirable to base our conclusions on as many stars as possible, irrespective of their individual proper motions.

In *Astron. Papers*, Vol. VIII, Part I, I have given normal equations for determining the precessional constant and the components X, Y and Z of the solar motion based on all the Bradley stars. The latter are divided into two classes, those having proper motions small enough to be used for precession, and those excluded on account of proper motion. The former were divided into six classes according to magnitude. As the results for solar motion were not fully investigated in that paper, I have now derived them from the combined normal equations (R.A.+Decl.) for each class of stars.

As the R.A. and Decl. equations give different values of the correction to the precession, I have used in all the equations in R.A. the value $+0''.24$ found from all the R.A.'s and in Decl. the value $+1''.34$ found from all the declinations. A separate solution for the stars of lower proper motion is found on p. 56 of the paper in question. The separate results for R, the parallactic motion of a star 90° from the apex, and A and D are as follows:

STARS OF SMALL PROPER MOTION.

Mag.	R	A	D	No. Stars	Wt.
	″	°	°		
1 to 2.9	6.59	263.1	+31.7	64	1
3.0 to 3.9	5.61	262.7	26.8	135	2
4.0 to 4.9	3.47	266.5	31.8	327	5
5.0 to 5.9	3.14	268.5	32.0	731	11
6.0 to 6.9	2.81	277.4	30.6	1034	16
7.0 +	2.86	278.2	+33.6	236	4

STARS OF LARGER PROPER MOTION.

All mag's	16″.7	276°.9	+31°.4	644	10

The mean result from the stars of small proper motion is

$$A = 272^\circ.5 \quad ; \quad D = +31^\circ.3$$

The progression in the values of A, and the agreement among those of D, are alike striking; but I see no cause to assign except the accidental dispersion of the proper motions.

The most complete discussion of the solar motion from stars of large proper motion with which I am acquainted, is that of STUMPE in *A.N.*, Bd. 125, No. 2999–3000, which is supplemented by a paper in Bd. 140, No. 3348. In the first paper the stars are classified as to amount of proper motion; in the second this work is repeated, and the results of a classification according to magnitude are added. The results of the latter classification are,

Mag. 1 to 5.5	$A = 263^\circ.8$	$D = 31^\circ.1$	$N = 284$
5.6 to 7.5	290.7	37.5	473
7.6 to <	286.7	46.9	238

The progression of the declination of the apex with the magnitude is remarkable, but does not seem attributable to any better defined cause than that already mentioned. Weighting STUMPE's results in proportion to the number of stars on which each depends, we have by the classification according to magnitude,

$$A = 283^\circ.1 \quad ; \quad D = +38^\circ.7$$

The classification according to proper motion gives, in the mean,

$$A = 281^\circ.8 \quad ; \quad D = +40^\circ.7$$

The difference merely accentuates the uncertainty of the result.

In the *Astronomical Journal*, Vol. IX, No. 213, BOSS has found, from 279 stars in the Albany zone,

$$A = 283^\circ.3 \quad ; \quad D = +44^\circ.1$$

If the proper motions in declination be reduced to my new standard by the correction $+0''.38$, the result for D will be diminished by $1^\circ.2$, so that

$$D = +42^\circ.9$$

In the preceding results are included, I believe, the results of all the independent data for the solar apex that have yet been worked up, and of all the readily available data except the 1200 proper motions found by AUWERS in his A.G. zone, $+30^\circ$ to $+35^\circ$. In seeking to combine them so as to get the most likely result, we are embarrassed by the systematic difference of 10° in the value of D from the Bradley stars and the totality of other stars, as well as by the equal difference in the value of A from the brighter and the fainter stars. The first discrepancy shows, in the faint stars with large proper motion, a preponderance of large negative motion in declination much greater than the possible systematic errors of the proper motions in declination generally. So far as the mere values of μ' are concerned, there is an obvious cause for this. In the apparent proper motions of stars all actual motions in the direction of the parallactic motion are exaggerated, while those in the opposite direction are belittled or reversed. But it is not clear to me that this would increase the derived parallactic motion in declination in a greater degree than that in R.A., and if it did not, the value of D would not be increased by the bias.

In seeking for a combined result we must note that some stars are included in more than one of the three determinations. Of STUMPE's stars about one-eighth, or 135 in all, are Bradley stars, while about 64 are in BOSS's zone. But, as it is impossible to separate the results from these common stars, we are obliged to allow their duplicate entrance into the final results, which will then be

	A	D	N
Br. stars of small p.m.	$272^\circ.5$	$+31^\circ.3$	2527
Br. stars of large p.m.	276.9	+31.4	644
STUMPE's stars	282.4	+39.7	995
BOSS's work	283.3	+42.9	279

A consideration of the whole subject leads me to give each result a weight w_0 proportional to the number of stars on which it depends, with these exceptions. In the case of A the first w_0 is multiplied by 0.5, and the second by 0.25, because only motions in declination are used. In the case of D the second w_0 is multiplied by 0.5, and the fourth, BOSS's, by 2.0.

Thus the weights taken are, in order,

$$\begin{array}{lll} \text{For } A & w = & 15,\ 2,\ 12,\ 4 \\ D & & 32,\ 4,\ 12,\ 7 \end{array}$$

There is evidently an uncertainty of several degrees as to the position; it will therefore suffice to use round numbers, and give

$$A = 277^\circ.5 = 18^h\,30^m$$
$$D = +35$$

as the most likely position of the apex at present.

III.

Parallactic Motion of the Fainter Stars.

The only new result I have to offer on this subject is one derived from AUWERS's comparison of the R.A.'s of his Berlin zone with LALANDE. In view of the fact that LALANDE's observations must be completely re-reduced before any definite result can be derived from them, I shall give no details of this very simple work, but merely state the result. When the comparisons are reduced to the A.G. standard with AUWERS's data, I find

$$A - L = 0^s.057 \cos(\alpha + 44^\circ)$$

a result which would place the apex in 226° of R.A., or about $51^\circ.5$ from its probable position. Taking the interval as seventy-four years we have for the centennial motion.

$$k \cos D = \frac{0''.86}{0.74} \cos 51^\circ.5 = 0''.72$$

From Boss's comparisons of his zone, *Astronomical Journal*, IX, p. 28, results

$$\begin{array}{ll} \text{From Lalande,} & M\cos D = +1''.11 \\ \text{From Bessel,} & +1.35 \end{array}$$

Giving these results the weights 3 and 2, and that just derived the weight 1, we have, as a mean result,

$$\begin{array}{ll} \text{Mag. 8.5,} & M\cos D = 1''.28 \\ & M = 1.56 \end{array}$$

Putting $v = 4$, this will give, for the mean parallax of stars of mag. 8.5,

$$\pi = 0''.0039$$

This result is derived directly from the parallactic motion, without assuming any law between the magnitudes of the stars and their distance.

IV.

The Mean Parallax of the Vogel Stars.

An estimate of this quantity may be made on the hypothesis that the indiscriminate mean of the relative motions of the stars in α, δ and ρ are the same in absolute amount. Omitting *Arcturus* as exceptional, we have, for the means of fifty motions,

$$\begin{array}{ll} \text{Mean of } \mu_\alpha \cos\delta & 0''.142 \\ \text{Mean of } \mu_\delta & 0.117 \\ \text{Mean of } v & 16.9 \text{ km. per sec.} \\ \text{or} \quad v = & 3.65 \text{ per year} \end{array}$$

$$\begin{array}{ll} \text{Hence, from R.A. motions, } \pi = & 0''.039 \\ \text{from Decl. motions,} & 0.032 \end{array}$$

The inclusion of *Arcturus* would have carried the means up to 0″.046 and 0″.043, but I conceive that the better result is obtained by omitting it. This is smaller than the usually adopted mean for the stars of magnitude 2.0. But it is larger than the result that would be derived from the mean parallactic motion of the eighty-seven Bradley stars of magnitude 1 to 2.9. This is approximately,

$$M = 0''.100 \pm$$

$$\pi = \frac{M}{v} = 0''.029$$

V.

Summary of Conclusions.

1. Kapteyn's determination of the absolute speed of the solar motion from the dispersion of Vogel's measures is probably very near the truth, so that we may put for the value of this speed in terms of the year and the earth's mean distance from the sun as units,

$$v = 3.5$$

2. Kapteyn's formulas for the mean parallax of stars of any magnitude, m, namely,

$$\pi_m = k^m \pi_0$$

where

$$k = \tfrac{1}{2}\sqrt{2}$$

is probably near the truth, at least up to the ninth magnitude.

3. The mean parallax of the brighter stars is probably less than that usually estimated. If we put

$$\pi_0 = 0''.07$$

giving, for the stars of magnitude 2.0,

$$\pi_2 = 0''.035$$

we shall probably be as near the truth as we can now get.

4. The most likely position of the solar apex is

$$\begin{array}{l} A = 277^\circ.5 = 18^h\,30^m \\ D = + \; 35^\circ \end{array}$$

but there is still an uncertainty of three or four degrees in the position.

CERASKI'S NEW VARIABLE IN *AURIGA*.

(1855) $5^h\ 17^m\ 7^s$, $+36^\circ\ 46'.5$

By J. A. PARKHURST.

I have 15 observations of this star, which was announced in *A.N.* 3529. 1898 Dec. 10 I found it $9^M.2$, after which it rose to a maximum, $8^M.7$, Dec. 24, and fell to $9^M.9$ at the last comparison, 1899 Feb. 1. The magnitudes depend on the DM. stars 36°1133, $9^M.5$; 1134, $9^M.5$; 1135, $9^M.5$, and 1141, $8^M.9$. The place of the variable, measured from the same stars is

$$\begin{array}{lll} \text{R.A.}\ 5^h\ 17^m\ 7^s.0 & \text{Decl.} +36^\circ\ 46'.5 & (1855) \\ \phantom{\text{R.A.}\ 5^h}\ 20\ \ 9.6 & \phantom{\text{Decl.} +36^\circ}\ 49.2 & (1900) \end{array}$$

Observed Magnitudes.

	M			M	
1898 Dec. 10	9.16		1898 Dec. 30	9.04	seeing poor
12	9.03		1899 Jan. 5	8.85	" "
13	8.96		10	9.04	
15	8.85		18	9.30	
17	8.88	moon,	24	9.59	
22	8.82	"	28	9.71	
26	8.73	"	Feb. 1	9.90	
28	8.96	seeing poor			

Marengo, Ill., 1899 *Feb.* 2.

OBSERVATIONS OF (334) *CHICAGO*,

MADE WITH THE 36-INCH REFRACTOR OF THE LICK OBSERVATORY,

By WILLIAM J. HUSSEY.

1898 Mt. Hamilton M.T.	⁎	No. Comp.	Planet – ⁎ Δα	Planet – ⁎ Δδ	Planet's apparent α	Planet's apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s	° ′ ″		
May 19 14 16 34	1	8 , 8	−0 12.88	+1 47.6	16 41 53.04	−16 30 9.5	9.257	0.841
June 2 11 41 12	3	10 , 10	+0 16.66	−3 3.3	16 32 37.24	−16 13 56.2	*n*8.026	0.848
12 15 0	3	7	+0 15.70	. . .	16 32 36.28	. . . .	8.548	. .
3 11 28 41	5	10 , 10	+0 9.35	−2 26.9	16 31 57.38	−16 12 57.9	*n*8.412	0.848
9 12 36 44	6	8 , 8	−0 3.33	−3 59.0	16 27 57.28	−16 7 34.5	9.235	0.840
10 11 26 3	8	10 , 10	−0 22.89	−0 23.2	16 27 20.37	−16 6 53.6	8.561	0.848
23 10 56 31	9	8 , 8	+0 8.59	−3 0.8	16 19 10.04	−16 0 31.1	8.992	0.845

Mean Places for 1898.0 of Comparison-Stars.

⁎	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 42 2.22	+3.70	−16 31 46.7	−10.4	Connected with ⁎2
2	16 43 30.30	+3.70	−16 35 34.8	−10.3	DM. −16°4353, Skinner, two Wash. M.C. Obs.
3	16 32 16.71	+3.87	−16 10 42.1	−10.8	Connected with ⁎4
4	16 35 58.61	+3.87	−16 9 59.3	−10.5	DM. −16°4328, Skinner, three Wash. M.C. Obs.
5	16 31 44.15	+3.88	−16 10 20.4	−10.6	Connected with ⁎4
6	16 27 56.65	+3.96	−16 3 24.4	−11.1	Connected with ⁎7
7	16 29 31.56	+3.96	−16 3 17.2	−11.0	DM. −15°4346, Skinner, two Wash. M.C. Obs.
8	16 27 39.30	+3.96	−16 6 19.3	−11.0	Connected with ⁎6
9	16 19 27.46	+3.99	−15 57 18.9	−11.4	DM. −15°4320, Skinner, two Wash. M.C. Obs.

$\Delta\alpha$ and $\Delta\delta$ have in all cases been measured directly with the micrometer.

Professor HARKNESS has kindly furnished some of the star-positions from the observations made at Washington for the A.G. Catalogue.

Mt. Hamilton, Cal., 1898 *Dec.* 19.

OBSERVATIONS OF SUSPECTED VARIABLES,

By J. A. PARKHURST.

CERASKI'S VARIABLE IN *Cepheus*.

This was announced by Prof. CERASKI in *A.N.* No. 3512, as 10ᴹ and diminishing in July, 1898. He gave its place from eye estimate as

R.A. $21^h\ 6^m.9$, Decl. +32° 28′.0, (1855)

In September I found a 12ᴹ star within 1′ of the place, and October 11 measured its position relative to the DM. star at $21^h\ 8^m\ 23^s$, 82° 24′.5, (1855), with the result:

R.A.	$21^h\ 6^m\ 34^s$	Decl. +82° 28′.9	(1855)
	3 33	39.8	(1900)

On this date the variable was estimated as 12ᴹ.0, as it was bright enough to set the micrometer thread upon without difficulty. It was the brightest of a group of 5 small stars, the other 4 lying from 1½′ to 3′ N. prec. Since then the variable has slowly faded, and in December and January has been invisible, though the four comparison stars are readily seen. The change amounts to at least 1ᴹ.

ANDERSON'S VARIABLE IN *Pegasus*.

This was announced in *A.N.* No. 3521, as falling from 9ᴹ.1 to 10ᴹ.1 in 1898 August and September. I found it at 11ᴹ.6, October 15, and have 15 observations since. It passed a minimum, at 12ᴹ.7, November 24, and rose to 10ᴹ.2 at the last comparison, 1899 January 11. Measures from the star DM. +13°1689 (Bonn VI) give the place

R.A.	$21^h\ 14^m\ 7^s.5$	Decl. +13° 50′ 17″	(1855)
	16 14.9	14 1 36	(1900)

There is an 8ᴹ.8 star, which I take to be DM. +13°1677, 3.4 sec. following, and 5′ 28″ south of the variable. If this is found in a catalogue it will give a more accurate place for the variable. There are two 11ᴹ.7 stars preceding the variable $6^s.3$ and $15^s.0$, respectively, on the same parallel, and a 11ᴹ.8, $10^s.0$ preceding, 0′.9 south.

Marengo, Ill., 1899 *Jan.* 12.

ELEMENTS AND EPHEMERIS OF *EROS*.

BY HENRY NORRIS RUSSELL.

The orbit which is here given is based on the following normal places, of which the first seven are those given by Dr. CHANDLER in *A.J.* 451, and the remaining two are formed from observations made at the Washburn Observatory, and published in *A.J.* 453.

1898 Gr. M.T.	No. Obs.	Observed Normals 1898.0 α	δ	O—C α	δ
		h m s	° ′ ″	s	″
Aug. 17.5	35	21 20 50.89	−6 21 27.3	−0.04	−0.7
21.5	26	21 8 16.15	−6 18 7.4	−0.01	+2.3
Sept. 1.5	19	20 55 35.58	−6 18 12.6	+0.21	+1.0
13.5	11	20 41 51.33	−6 21 4.2	−0.03	−0.2
23.5	14	20 36 19.66	−6 20 43.0	−0.02	+0.4
Oct. 11.5	2	20 39 2.16	−6 2 3.1	+0.07	+0.1
Nov. 11.5	4	21 12 34.17	−4 5 16.6	−0.07	−2.1
Dec. 8.5	4	22 0 44.48	−0 38 4.7	+0.21	+0.5
28.5	2	22 44 0.54	+2 57 39.2	−0.08	+0.1

In computing the elements a suggestion of Dr. CHANDLER's was followed, and the value of μ determined by him from the observations of the three oppositions of 1893–4 1896 and 1898 was assumed to be sensibly accurate, and used as a basis of further calculation. The other five elements were determined by varying the ratio of the extreme geocentric distances. The elements finally obtained are as follows. The deviations O—C of the respective normal places are given above.

Epoch 1898 Aug. 31.5 Greenwich M.T.

$$\begin{aligned} M &= 221^\circ\ 38'\ 37''.8 \\ \omega &= 177\ 38\ 15.2 \\ \Omega &= 303\ 29\ 57.3 \\ i &= 10\ 49\ 31.0 \\ \varphi &= 12\ 52\ 27.9 \end{aligned} \quad \left.\begin{matrix}\\ \\ \\ \end{matrix}\right\} 1898.0$$

$$\log a = 0.1637876$$
$$\mu = 2015''.2326$$

Period 643.10 days

EQUATORIAL COORDINATES 1899.0

$$x = [9.9916090]\, r \sin(211^\circ\ 37'\ 33''.6 + v)$$
$$y = [9.9414807]\, r \sin(116\ 34\ 2.3 + v)$$
$$z = [9.7081149]\, r \sin(137\ 6\ 33.3 + v)$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1899	α	δ	log Δ	Mag.
	h m s	° ′ ″		
Mar. 1.5	1 37 20.19	+17 27 55.1	0.2170	12.5
3.5	1 43 52.53	17 54 20.7		
5.5	1 50 29.31	18 20 18.0	0.2179	
7.5	1 57 10.51	18 45 43.7		
9.5	2 3 56.13	19 10 34.7	0.2188	12.5
11.5	2 10 46.14	19 34 48.1		
13.5	2 17 40.52	19 58 21.0	0.2195	
15.5	2 24 39.24	20 21 10.3		
17.5	2 31 42.26	20 43 13.1	0.2202	12.4
19.5	2 38 49.53	21 4 26.4		
21.5	2 46 0.98	+21 24 47.4	0.2208	

COMET *a* 1899.

A dispatch from Prof. LEWIS SWIFT, of the Lowe Observatory, dated March 3, $8^h\,25^m$ A.M., received at the Harvard College Observatory, announced the discovery of a comet in about $\alpha = 3^h\,45^m$, $\delta = -29°$. It was large, visible to the naked eye, with a short tail, and slow motion. Later, Prof. KEELER telegraphed the following observations by Prof. HUSSEY at the Lick Observatory, and Capt. DAVIS one by Prof. BROWN at the Washington Naval Observatory:

	α	δ	
	h m s	° ′ ″	
1899 March 4.6356 Gr. M.T.	α = 3 48 4.3	δ = −27 7 32	Hussey
5.5467	3 42 46.9	−25 45 49	Brown
5.6478	3 42 12.6	−25 36 54	Hussey
6.6523	3 36 44.5	−24 8 32	Hussey

COMET *b* 1899.

Prof. KREUTZ telegraphs the discovery of a faint comet by WOLF, probably a return of TUTTLE's comet, in the following position:

1899 March 5.325 Gr. M.T. $\alpha = 1^h\,16^m.0$, $\delta = +31°\,38'$. Daily motion, $+3^m\,44^s$ and 14′ southward.

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ON THE SOLUTION OF DELAUNAY'S CANONICAL SYSTEM OF EQUATIONS.

BY ORMOND STONE.

If we put*

$$\Sigma_i p_i \frac{dq_i}{dt} - T - U + R = 0 \tag{1}$$

HAMILTON'S canonical equations of motion become

$$\frac{dp_i}{dt} = \frac{\partial R}{\partial q_i} \quad , \quad \frac{dq_i}{dt} = -\frac{\partial R}{\partial p_i} \tag{2}$$

in which

$$p_i = \frac{\partial T}{\partial \frac{dq_i}{dt}} \tag{3}$$

The q_i's are the generalized coordinates of the disturbed body, say the moon, and R is DELAUNAY'S so-called perturbative function. T is half the square of the moon's velocity, and U is the corresponding force function.

DELAUNAY, in his *Théorie de la Lune,* chose as q_i's

l = the moon's mean anomaly,
g = the angular distance of the perihelion from the node,
h = the longitude of the node counted from a fixed point in the fundamental plane;

in each case the reference being to the instantaneous Keplerian ellipse; whence the p_i's become

$$L = \sqrt{\mu a} \quad , \quad G = \sqrt{\mu a(1-e^2)} \quad , \quad H = \sqrt{\mu a(1-e^2)}\cos i$$

in which μ is the constant of the system, a is the semi-major axis, e the eccentricity, and i the inclination of the moon's orbit.

In the Proceedings of the London Mathematical Society (Vol. XXVII, p. 385), Professor E. W. BROWN gives a simple and interesting solution of DELAUNAY'S canonical system of equations by means of HAMILTON'S principal function. In the following solution HAMILTON'S function is avoided.

*Dr. G. W. HILL. On the Differential Equations of Motion (*The Analyst*, Vol. I, p. 200). Also see Dr. HILL'S Lectures on Celestial Mechanics.

In the first approximation, if R be neglected, L, G, H become constants. As a second approximation let us put

$$R = R_0 = -B - A\cos\theta \tag{4}$$

in which B and A are assumed to be functions of L, G, H, only, and

$$\theta = il + i'g + i''h + \lambda + q \tag{5}$$

in which i, i', i'' are integers, λ is a quantity supposed to vary uniformly with the time, and q is a constant. (4) gives

$$\frac{1}{i}\frac{\partial R_0}{\partial l} = \frac{1}{i'}\frac{\partial R_0}{\partial g} = \frac{1}{i''}\frac{\partial R_0}{\partial h} = \frac{\partial R_0}{\partial \theta} \tag{6}$$

or by means of (2)

$$\frac{1}{i}\frac{dL}{dt} = \frac{1}{i'}\frac{dG}{dt} = \frac{1}{i''}\frac{dH}{dt} = \frac{d\Theta}{dt} \quad \text{say,} \tag{7}$$

whence by integration

$$\left.\begin{aligned} L &= L_0 + i\,\Theta \\ G &= G_0 + i'\Theta \\ H &= H_0 + i''\Theta \end{aligned}\right\} \tag{8}$$

in which L_0, G_0, H_0 are constants of integration, and it is seen at once that R_0 may be expressed as a function of Θ and θ only. Putting $\nu = \frac{d\lambda}{dt}$ and differentiating (5) with reference to t.

$$\left.\begin{aligned} \frac{d\theta}{dt} &= -i\frac{\partial R_0}{\partial L} - i'\frac{\partial R_0}{\partial G} - i''\frac{\partial R_0}{\partial H} + \nu \\ &= -\frac{\partial R_0}{\partial \Theta} + \nu = -\frac{\partial(R_0 - \nu\Theta)}{\partial \Theta} \end{aligned}\right\} \tag{9}$$

Also (6) and (7) give

$$\frac{d\Theta}{dt} = \frac{\partial R_0}{\partial \theta} = \frac{\partial(R_0 - \nu\Theta)}{\partial \theta} \tag{10}$$

whence

(11) $$\frac{d\,(R_0-\nu\Theta)}{dt} = \frac{\partial\,(R_0-\nu\Theta)}{\partial\Theta}\frac{d\Theta}{dt} + \frac{\partial(R_0-\nu\Theta)}{\partial\theta}\frac{d\theta}{dt} = 0$$

and by integration

(12) $$R_0 - \nu\Theta = \Psi_0$$

or

(13) $$R_0 = \Psi_0 + \nu\Theta = -B - A\cos\theta$$

in which Ψ_0 is a constant. If by means of (8) A and B be expressed in terms of L_0, G_0, H_0, and Θ, the solution of (13) may be performed so as to give Θ in a series of terms involving cosines and multiples of θ and constant coefficients. Since Ψ_0 is arbitrary we may assume it to be a function of L_0, G_0, H_0 determined by some arbitrary condition; this condition we will assume to be that the non-periodic term in Θ is equal to zero. We may therefore assume

(14) $$\Theta = \sum_1^\infty{}_j\, j\Psi_j \cos j\theta$$

in which the Ψ_j's are functions of L_0, G_0, H_0 determined by the solution of (13). As a consequence of the assumption that Θ contains no non-periodic term, L_0, G_0, H_0 are the non-periodic, and $i\Theta$, $i'\Theta$, $i''\Theta$ are the periodic portions of L, G, H, respectively. Since L, G, H are constants in the undisturbed orbit, Θ is a small quantity of the order of the perturbations. This fact makes it possible to solve (13) by successive approximations. It will also be convenient to introduce new arbitraries a_0, i_0, e_0 such that

$$L_0 = \sqrt{\mu a_a}\quad,\quad G_0 = L_0\sqrt{1-e^2_0}\quad,\quad H_0 = G_0\cos i_0$$

or,

$$a_0 = \frac{L_0^{\,2}}{\mu}\quad,\quad e_0 = \sqrt{1-\frac{G_0^{\,2}}{L_0^{\,2}}}\quad,\quad \gamma = \sin\tfrac{1}{2}\,i_0 = \sqrt{\tfrac{1}{2}-\frac{H_0}{2G_0}}$$

relations identical with those between L, G, H and a, e, i.

We may now introduce the new variable l_0 obtained from

(19) $$\left\{\begin{aligned}\frac{dl_0}{dt} &= -\frac{\partial\Psi_0}{\partial L_0}\\ &= -\frac{\partial(R_0-\nu\Theta)}{\partial a}\frac{\partial L}{\partial L_0} - \frac{\partial(R_0-\nu\Theta)}{\partial\Theta}\frac{\partial\Theta}{\partial L_0}\\ &= \frac{dl}{dt} + \sum_1^x{}_j\, j\frac{\partial\Psi_j}{\partial L_0}\cos j\theta\,\frac{d\theta}{dt}\end{aligned}\right.$$

whence by integration

$$l_0 = l + \sum_1^\infty{}_j\frac{\partial\Psi_j}{\partial L_0}\sin j\theta$$

or

(20) $$\left\{\begin{aligned} l &= l_0 - \sum_1^\infty{}_j\frac{\partial\Psi_j}{\partial L_0}\sin j\theta\\ \text{similarly}\qquad g &= g_0 - \sum_1^\infty{}_j\frac{\partial\Psi_j}{\partial G_0}\sin j\theta\\ h &= h_0 - \sum_1^\infty{}_j\frac{\partial\Psi_j}{\partial H_0}\sin j\theta\end{aligned}\right.$$

l_0, g_0, h_0, L_0, G_0, H_0 may be considered as elements of an intermediate orbit connected with the elliptic canonical elements by the relations (8) and (20). If $R = R_0$

$$L_0,\ G_0,\ H_0,\quad \frac{\partial\Psi_j}{\partial L_0}\ ,\quad \frac{\partial\Psi_j}{\partial G_0}\ ,\quad \frac{\partial\Psi_j}{\partial H_0}$$

will be constants. For the true value of R, however, this will not, in general, be the case. Nevertheless the instantaneous values of the elliptic elements will give instantaneous values of the intermediate elements, and from equations (19) may be obtained the corresponding instantaneous values of

$$\frac{dl}{dt}\ ,\quad \frac{dg}{dt}\ ,\quad \frac{dh}{dt}$$

If now we put $R-\nu\Theta$ for R in equations (1) and (2), it may be seen at once that these equations in the changed form are satisfied by the canonical system l, g, h, θ, L, G, H, Θ, whence

$$\Theta = \frac{\partial T}{\partial\dfrac{d\theta}{dt}}$$

and

$$\frac{dT}{\partial\dfrac{dl}{dt}} = \frac{\partial T}{\partial\dfrac{dl_0}{dt}}\ \frac{\partial\dfrac{dl_0}{dt}}{\partial\dfrac{dl}{dt}} + \frac{\partial T}{\partial\dfrac{d\theta}{dt}}\ \frac{\partial\dfrac{d}{dt}}{\partial\dfrac{dl}{dt}}$$

or

$$L = \frac{\partial T}{\partial\dfrac{dl_0}{dt}} + i\Theta$$

Comparing this with the first of equations (8) we see at once that

$$L_0\left(=\frac{\partial T}{\partial\dfrac{dl_0}{dt}}\right)\ \text{and}\ l_0$$

are canonically related; whence

$$\frac{dL_0}{dt} = \frac{\partial(R-\nu\Theta)}{\partial l_0}\quad,\quad \frac{dl_0}{dt} = -\frac{\partial(R-\nu\Theta)}{\partial L_0}$$

or putting $R_1 = R - R_0$, equation (12) gives

$$\begin{aligned} \frac{dL_0}{dt} &= \frac{\partial(\Psi_0+R_1)}{\partial l_0}\ , & \frac{dl_0}{dt} &= -\frac{\partial(\Psi_0+R_1)}{\partial L_0}\\ \text{similarly}\qquad \frac{dG_0}{dt} &= \frac{\partial(\Psi_0+R_1)}{\partial g_0}\ , & \frac{dg_0}{dt} &= -\frac{\partial(\Psi_0+R_1)}{\partial G_0}\\ \frac{dH_0}{dt} &= \frac{\partial(\Psi_0+R_1)}{\partial h_0}\ , & \frac{dh_0}{dt} &= -\frac{\partial(\Psi_0+R_1)}{\partial H_0}\end{aligned}$$

As a second approximation we may assume R_1 to consist of a single term, and proceed as before; and so on until all the terms involved in R have been considered.

MAXIMA AND MINIMA OF LONG-PERIOD VARIABLES,

By J. A. PARKHURST.

267. *V Andromedae.*

Following the minimum reported in *A.J.* 456 the star rose quickly from 10ᴹ.5 on 1898 Nov. 19. to a maximum, 8ᴹ.8 (compared with 5 neighboring DM. stars) Dec. 20, then fell more slowly to 10ᴹ.1 at the last comparison 1899 Feb. 7. At maximum it was 0ᴹ.1 fainter than DM. 35°154, which is rated at 9ᴹ.22 photometric, in H.C.O. XXIV. I have 10 observations in the above interval.

294. *W Cassiopeae.*

I have 8 observations between the series reported in *A.J.* 456 and 1899 Jan. 24. The star rose very slowly from its minimum at 12ᴹ to a maximum at 8ᴹ.4 about 1898 November 14, though it is so nearly stationary in light during October and November that the maximum may have occurred as much as a month earlier. The fall, as usual, was more rapid than the rise, reaching 10ᴹ.0 at the last comparison.

659. *X Cassiopeae.*

Since the maximum reported in *A.J.* 434 this star fell slowly, reaching 12ᴹ 1898 Mar. 13, where it remained with some fluctuations till October. It then rose slowly, reaching 11ᴹ about Dec. 3, and remained at that brightness till the last comparison, 1899 Feb. 15. No time can be determined for the minimum, and the maximum expected in November is at least much delayed.

2376. *S Lyncis.*

Following the minimum reported in *A.J.* 456 I have 16 observations between its reappearance at 11ᴹ.8, 1898 July 6 and 1899 Jan. 14. It rose steadily to a maximum, fairly well fixed at 1898 Oct. 1 (possibly 5 or 10 days earlier) at 9ᴹ.4, and then fell at about the same rate to 12ᴹ.0 at the last comparison, after which it was indistinguishable with the 6.2-inch from its close companion. My observations now cover about one and one-half complete cycles, including the descending branches of the light-curves following two successive maxima. The mean interval between points of equal brightness on these two branches is 293 days. Assuming this as the period, the dates of the two preceding maxima would be 1897 Feb. 22 and Dec. 12. As a check on this we have Rev. Mr. Anderson's observations — 1897 April 21, 10ᴹ.5 (10ᴹ.4 by this curve). and Dec. 17, 9ᴹ.5 (9ᴹ.5 by the curve). In seeming contradiction stands Dr. Hartwig's estimate of 618 days as the period, with a maximum 1897 Sept. 20 (*Vierteljahrsschrift*, XXXIII, 347).

5583. *X Librae.*

This star was first seen with the Yerkes 12-inch glass 1898 June 25 at 13ᴹ.8. It rose rapidly to a maximum about 9ᴹ.5 Aug. 21, or perhaps 10 days later, for the series closed Sept. 3, with a fall of only 0ᴹ.1 or 0ᴹ.2. The curve seems to show that the star was 10 to 20 days ahead of the ephemeris.

5601. *S Ursae Minoris.*

A maximum, 1898 Sept. 5, at 7ᴹ.8, is indicated by 9 observations between 1898 June 17 and Dec. 17. The period is evidently a few days shorter at present than that given in the Third Catalogue.

6419. *T Draconis.*

The minimum given in *A.J.* 434 was followed by a rapid rise to a maximum 1898 May 10, at 8ᴹ.0, but the fall was so slight during the rest of May and June that the maximum might be placed even a month later. It continued to fall slowly, reaching 11ᴹ Dec. 18. The maximum is covered by 14 observations.

6549. *W Lyrae.*

I have 14 observations since those reported in *A.J.* 456. They show a well-defined maximum 1898 Nov. 16, at 7ᴹ.6. The star passed 10ᴹ rising 1898 Sept. 20, and falling 1899 Jan. 9. As usual, the rate of rise and fall were about equal. The interval since the last maximum is 194 days. When this is carried back to the Lund observations in 1880 (*A.N.* 3329) for which the epoch is −32, the period is corrected to 195.5 days: carried to the DM. observations in 1858, epoch −73, and 1856, epoch −77 (*A.N.* 3329) the resulting period is 196.0 days. The last named observations are especially conclusive, as the star was then clearly just past its maximum.

6871. *V Lyrae.*

The season's observations began 1898 June 25, when the variable was below the limit of the Yerkes 12-inch refractor. It continued invisible through July, and was first seen Aug. 18, at about 13ᴹ.5. The rise was then rapid to a maximum Oct. 10, at 9ᴹ.0. The curve gives some indications of the secondary maximum, Nov. 10, mentioned by Mr. H. M. Parkhurst in *A.J.* 456, but the evidence is not conclusive; however, a well-marked secondary maximum at 11ᴹ.1 is shown for 1899 Jan. 10, after which the fall was again rapid, reaching very near 13ᴹ at the last comparison, Feb. 15. I have 20 observations in all, covering nearly two-thirds the period.

7085. *RT Cygni.*

I have 14 observations between 1898 Aug. 30 and 1899 Jan. 21. The star faded from 7ᴹ.2 to a well-marked minimum at 10ᴹ.8, Nov. 22, and rose rapidly to 7ᴹ.5 at the last comparison. This is the brightest minimum I have observed, the previous one, 1898 May 23, at 11ᴹ.7, being the next brightest.

7379. *ST Cygni.*

After the maximum reported in *A.J.* 456, this star was below my limit from 1898 Nov. 1 at $12^M.8$, to Dec. 30 at $12^M.4$. It had risen to $10^M.7$ at the last comparison, Feb. 28. The curve indicated a minimum, $< 13^M$ about Nov. 18. My observations now cover the ascending branches of two light-curves, giving for the intervals between points of equal brightness 329 days. In connection with the maximum of 1893 Sept. 30, given by Dr. Hartwig in the *Vierteljahrsschrift*, XXXIII, 348, the period would seem to be $\frac{1720}{n}$ days. If n is 5, the resulting period, 344 days, is in fair agreement with the above intervals.

7492. *RZ Cygni.*

Since the maximum reported in *A.J.* 441 this star faded to a minimum, $11^M.8$, 1898 July 2, then rose to a secondary maximum, $11^M.0$, Sept. 27, after which it fell slowly to $11^M.6$ at the last comparison, 1899 Jan. 28. On account of the extreme redness of the star it is perhaps not surprising that my results do not agree well with those published by Dr. Hartwig in *Vierteljahrsschrift*, XXXIII, 349, but one day before his "bright maximum," 1895 Nov. 20, I found it $11^M.2$, and slowly decreasing, and I have noted a rise above 11^M only to maxima at intervals of 583 days.

7502. *X Delphini.*

My search for this star began 1896 Oct. 22, but it was not identified till 1897 July 1. Then micrometric comparison with +17°4449 (Bonn VI) and 17°4451 (Berlin *Ast. Gesell. Catal.*) gave the place,

R.A. $20^h\,48^m\,13^s.2$	Decl $+17°\ 5'\ 33''$	(1855)
$50\ \ 17.7$	$15\ \ 40$	(1900)

which is 1'.4 north of the DM. place. The variable was then $11^M.5$, and fading, and was not seen again till Oct. 30 at $11^M.8$, Nov. 16 at $11^M.5$, and 1898 Jan. 16, at $8^M.7$. It was next looked for in June and July with the Yerkes 12-inch, and first seen July 12, at $12^M.2$. After this 18 observations showed a steady rise to maximum, 1898 Oct. 12, at $8^M.4$, followed by a slightly slower fall to $11^M.6$, when last seen 1899 Jan. 8. Applying this curve to the previously observed points, a minimum is suggested about 1897 Sept. 10, $< 13^M$, and a maximum, 1898 Jan. 24. The period seems to be about 284 days.

7792. *SS Cygni.*

Since the report in *A.J.* 441, I have observed the following maxima:

Short, 1898 July 21.8	Long, 1898 Sept. 9.6
Nov. 13.0	1899 Jan. 10.5

Detailed results will be found in *Popular Astronomy* for March, 1899, where I have deduced the following elements for the time of passing $9^M.35$ on the rise:

For short maxima, $T =$ 1897 Apr. $24.0 + 107.7\,E + 1.1\,E^2$
For long maxima, $T =$ June $4.4 + 112.6\,E + 0.7\,E^2$

The residuals from these elements since the above zero-epochs vary from -4.2 to $+3.9$ days.

7896. *V Pegasi.*

The star was first seen this season with the Yerkes 12-inch 1898 June 27, at about 13^M. It rose steadily to a maximum Oct. 1 at $8^M.5$, then fell at the same rate to 12^M at the last comparison 1899 Jan. 8. The maximum magnitude is based on the DM. estimates of +5°4926, $8^M.8$; 4927, $9^M.4$; and 4929, $8^M.4$. A neighboring comparison-star, +5°4922, whose DM. place is $21^h\,53^m\,12^s.8$, $+5°\,25'.3$ is wrong both in the DM. catalogue and chart. Its place is $53^m\,17^s.6$, $+5°\,22'.8$, (1855).

8324. *V Cassiopeae.*

I have 15 observations between 1898 Oct. 15 and 1899 Feb. 15, showing a steady rise from $10^M.3$ to a maximum, $7^M.4$, 1898 Dec. 22, and a fall to $10^M.2$ at the last comparison. The 8 maxima and 8 minima observed since 1894 give the elements of maximum:

$$1893 \text{ Nov. } 25\ (241\ 2793.8) + 231.47\,E\ ,\quad M - m = 114^d.$$

Including the Harvard and DM. observations (*A.J.* 358) the elements become

$$J.D.\ 241\ 2794.9 + 231.26\,E$$

A NEW STAR IN *SAGITTARIUS*.

Prof. E. C. Pickering announces that, from an examination of the Draper Memorial photographs, Mrs. Fleming has discovered a new star in the constellation *Sagittarius*. Its position for 1900 is $\alpha = 18^h\,56^m.2$, $\delta = -13°\,18'$. It was too faint to be photographed on eighty plates taken between 1888 Oct. 18, and 1897 Oct. 27, although stars as faint as the fifteenth magnitude appear on some of them. It appears on eight photographs taken while it was bright. On 1898 March 8, it was of the fifth magnitude, and on 1898 April 29, of the eighth magnitude. A plate taken 1899 March 9, shows that the star is still visible and is of the tenth magnitude. Two photographs show that its spectrum resembles those of other new stars. Fourteen bright lines are shown, six of them due to hydrogen.

A NEW SATELLITE OF *SATURN*.

Prof. E. C. PICKERING announces that a new satellite of *Saturn* has been discovered by Prof. WILLIAM H. PICKERING at the Harvard College Observatory. It is three and a half times as distant from *Saturn* as *Iapetus*. The period is about seventeen months, and the magnitude is 15.5. The satellite appears upon four plates taken at the Arequipa Station with the Bruce Photographic Telescope.

OBSERVATIONS OF ASTEROIDS AND COMETS,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 12-INCH EQUATORIAL,

BY PROF. EDGAR FRISBY, U.S.N.

[Communicated by Prof. WM. HARKNESS, U.S.N., Astronomical Director.]

1898 Washington M.T.	*	No. Comp.	Object — * $\Delta\alpha$	Object — * $\Delta\delta$	Apparent α	Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			(24) *Themis.*					
			m s	′ ″	h m s	° ′ ″		
May 17 11 26 34.0 (h m s)	1	20 , 5	+0 5.17	+ 3 26.4	14 21 56.75	−14 19 35.1	8.9956	0.8465
18 11 25 24.0	1	20	−0 34.06	. . . .	14 21 17.52	. . . .	9.0250	. .
			(7) *Iris.*					
May 17 11 51 23.4	2	20 , 4	+1 43.81	− 6 27.1	16 9 42.95	−23 37 30.8	*n*8.8785	0.8894
18 12 2 33.0	2	20	+0 42.43	. . . .	16 8 41.58	. . . .	*n*8.5839	. .
31 11 16 1.5	3	15 , 3	−0 50.34	−12 46.8	15 55 24.81	−22 37 2.8	*n*7.1646	0.8894
June 6 10 44 55.4	4	20 , 4	+0 53.73	+18 34.2	15 49 37.78	−22 9 28.5	*n*7.7075	0.8875
9 11 0 10.8	5	20 , 4	−0 33.76	−15 11.4	15 46 52.68	−21 55 23.3	8.7725	0.8855
			(76) *Freia.*					
July 18 11 3 46.1	6	12 , 3	+1 53.21	−10 18.2	18 38 19.83	−20 34 47.3	8.4626	0.7850
			(148) *Gallia.*					
Aug. 15 12 5 18.6	7	19 , 4	+3 5.33	−14 9.5	21 52 42.25	−12 40 56.7	*n*8.2625	0.8896
			(113) *Amalthea.*					
Oct. 10 10 47 0.6	8	6 , 2	+0 18.97	+17 46.9	0 38 13.11	− 4 5 48.7	*n*8.8114	0.7781
12 10 19 32.2	8	24 , 5	−1 31.75	+ 7 2.5	0 36 22.38	− 4 16 33.3	*n*8.9988	0.7790
			(19) *Fortuna.*					
Oct. 12 10 54 37.6	9	15 , 3	−2 27.73	− 2 48.0	0 43 13.20	+ 5 30 46.0	*n*8.6583	0.8849
			Eros.					
Nov. 16 8 13 31.4	10	20 , 4	−0 36.41	+ 9 8.0	21 18 59.86	− 3 44 43.8	9.4693	0.7679
Dec. 9 7 29 37.6	11	5 , 1	−0 37.12	+ 2 13.3	22 2 52.97	− 0 23 38.2	9.4768	0.7440
			(33) *Polyhymnia.*					
Dec. 14 11 8 48.1	12	5 , 1	−1 16.42	− 7 17.3	5 23 56.31	+26 16 43.5	8.9478	0.2895
			(139) *Juewa.*					
Dec. 17 12 8 9.2	13	5 , 1	−0 19.80	−12 56.4	6 0 58.49	+40 51 20.2	*n*8.1662	*n*9.5186
			COMET *h* 1898.					
Sept. 17 16 42 10.0	14	15 , 3	−0 1.53	+ 2 5.2	10 5 48.52	+28 22 37.2	9.7152	0.6527
18 16 23 19.8	15	20 , 4	−0 27.52	−10 32.8	10 11 0.60	+27 44 42.3	*n*9.7151	0.6764
23 16 47 52.1	16	15 , 3	−1 8.63	+ 7 17.6	10 43 58.80	+24 3 47.5	*n*9.7008	0.7169
27 16 32 46.4	17	25 , 5	+0 13.41	− 1 16.4	11 9 45.98	+20 33 39.1	*n*9.6708	0.7210
28 16 46 14.7	18	20 , 4	+1 16.78	− 2 14.2	11 16 17.16	+19 35 58.2	*n*9.6884	0.7142
29 16 17 23.0	19	18	+0 18.54	. . . .	11 22 41.26	. . . .	*n*9.6842	. .
			COMET *i* 1898.					
Oct. 22 7 5 13.5	20	24 , 4	−0 21.39	−10 22.6	15 22 3.37	+55 47 34.0	9.9133	0.4520
23 10 24 19.0	21	20 , 4	+3 12.21	+ 5 16.7	15 43 16.73	+52 46 8.1	9.7513	0.8465
24 7 8 3.05	22	20 , 4	+0 17.15	+ 8 57.0	15 57 26.60	+50 20 4.0	9.8526	0.4196
27 6 50 19.8	23	20 , 4	+2 27.73	− 4 18.5	16 35 45.67	+41 31 22.3	9.7869	0.5750
28 7 49 36.3	24	25 , 5	−0 29.11	−11 53.7	16 46 2.54	+38 27 37.0	9.6629	0.5610
Nov. 1 7 2 7.0	25	20 , 4	+0 3.03	+10 43.8	17 15 24.16	+27 34 10.0	9.6834	0.5714
2 6 52 40.0	26	20 , 4	+2 37.94	+ 6 49.8	17 20 55.59	+25 5 52.1	9.6636	0.5772
3 6 39 26.4	27	20 , 4	−0 17.70	−12 0.6	17 25 54.43	+22 45 9.6	9.6421	0.5830

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	14 21 48.17	+3.41 / +3.41	−14 22 42.4	−19.1	Radcliffe (3) 3739
2	16 7 55.32	+3.82 / +3.83	−23 30 50.2	−13.5	Oe. Arg. S. 15403
3	15 56 11.22	+3.93	−22 24 2.0	−14.0	Oe. Arg. S. 15133
4	15 48 40.06	+3.99	−22 27 48.0	−14.7	Oe. Arg. S. 14997
5	15 47 22.42	+4.02	−21 39 57.0	−14.9	Yarnall 6654
6	18 36 22.04	+4.58	−20 24 31.0	+ 1.9	Radcliffe (3) 4909
7	21 49 32.41	+4.51	−12 27 9.1	+21.9	Radcliffe (3) 5903
8	0 37 49.53	+4.61 / +4.60	− 4 24 5.2	+29.6 / +29.4	Radcliffe (3) 138
9	0 45 36.30	+4.63	+ 5 33 4.0	+30.0	Bonn VI + 5°113
10	21 19 32.71	+3.56	− 3 54 12.4	+20.6	Radcliffe (3) 5776
11	22 3 26.63	+3.46	− 0 26 14.6	+23.1	¼(Weisse + Schj. + Cambridge + Munich)
12	5 25 6.41	+6.32	+26 23 54.8	+ 6.0	Graham, Cambridge (Eng.) A.G. Catal. 2488
13	6 1 10.97	+7.32	+41 4 16.2	+ 0.4	Bonn 5014
14	10 5 47.69	+2.36	+28 20 45.5	−13.5	Graham, Cambridge (Eng.) A.G. Catal. 5241
15	10 11 25.78	+2.34	+27 55 28.8	−13.7	Graham, Cambridge (Eng.) A.G. Catal. 5290
16	10 45 5.17	+2.26	+23 56 44.4	−14.5	Becker, Berlin A.G. Catal. 4114
17	11 9 0.37	+2.20	+20 35 10.3	−14.8	Becker, Berlin A.G. Catal. 4217
18	11 14 28.18	+2.20	+19 38 27.2	−14.8	Auwers, Berlin A.G. Catal. 4407
19	11 22 20.55	+2.17	. . . . . .	. . .	Auwers, Berlin A.G. Catal. 4432
20	15 22 25.05	−0.29	+55 58 3.6	− 7.0	Helsingfors and Gotha A.G. Catal. 8363
21	15 40 4.52	0.00	+52 40 56.2	− 4.8	Rogers, Cambridge A.G. Catal. 4821
22	15 47 9.26	+0.19	+50 11 9.7	− 2.7	Rogers, Cambridge A.G. Catal. 4886
23	16 33 17.13	+0.81	+41 35 39.6	+ 1.2	Deichmüller, Bonn A.G. Catal. 10632
24	16 46 30.59	+1.06	+38 39 28.1	+ 2.6	Lund Zones, 245,14 and 253,14
25	17 15 19.85	+1.58	+27 23 21.6	+ 4.6	Graham, Cambridge A.G. Catal. 8135
26	17 18 15.97	+1.68	+24 58 57.8	+ 4.5	Graham, Cambridge A.G. Catal. 8165
27	17 26 10.35	+1.78	+22 57 5.2	+ 5.0	Becker, Berlin A.G. Catal. 6003

EPHEMERIS OF COMET *j* 1898 (*CHASE*),

Continued from *A.J.* 454,

BY E. F. CODDINGTON.

1899 G.M.T.	α	δ	log Δ	Br.
	h m s	° ′ ″		
April 3.5	10 44 16.87	+37 36 49.3	0.3851	0.46
5.5	44 8.45	37 27 23.5	0.3907	
7.5	44 4.63	37 17 16.0	0.3963	0.43
9.5	44 5.44	37 6 28.6	0.4019	
11.5	44 10.86	36 55 3.7	0.4076	0.40
13.5	44 20.88	36 43 3.4	0.4132	
15.5	44 35.43	36 30 30.0	0.4189	0.38
17.5	44 54.46	36 17 26.2	0.4246	
19.5	45 17.85	36 3 53.3	0.4304	0.35
21.5	45 45.53	35 49 52.8	0.4361	
23.5	46 17.38	35 35 26.9	0.4417	0.33
25.5	46 53.27	35 20 37.9	0.4474	
27.5	47 33.11	35 5 26.9	0.4531	0.30
29.5	48 16.80	34 49 55.7	0.4588	
May 1.5	49 4.25	34 34 5.0	0.4644	0.28
3.5	49 55.30	34 17 55.7	0.4700	
5.5	50 49.86	34 1 29.6	0.4755	0.26
7.5	51 47.83	33 44 48.4	0.4811	
9.5	52 49.11	33 27 52.9	0.4866	0.25
11.5	53 53.61	33 10 43.9	0.4921	
13.5	55 1.20	32 53 22.7	0.4975	0.23
15.5	56 11.77	32 35 50.4	0.5029	
17.5	10 57 25.18	+32 18 8.2	0.5083	0.22
May 19.5	10 58 41.31	+32 0 17.3	0.5135	
21.5	11 0 0.04	31 42 18.2	0.5187	0.20
23.5	1 21.28	31 24 11.5	0.5240	
25.5	2 44.90	31 5 58.1	0.5293	0.19
27.5	4 10.79	30 47 39.0	0.5344	
29.5	5 38.87	30 29 14.5	0.5395	0.18
31.5	7 9.02	30 10 45.2	0.5445	
June 2.5	8 41.18	29 52 11.5	0.5495	0.17
4.5	10 15.27	29 33 34.0	0.5544	
6.5	11 51.22	29 14 53.2	0.5593	0.16
8.5	13 28.95	28 56 9.8	0.5641	
10.5	15 8.38	28 37 24.4	0.5688	0.15
12.5	16 49.44	28 18 37.8	0.5735	
14.5	18 32.00	27 59 50.0	0.5782	0.14
16.5	20 15.97	27 41 1.3	0.5848	
18.5	22 1.30	27 22 12.4	0.5873	0.13
20.5	23 47.95	27 3 24.3	0.5918	
22.5	25 35.83	26 44 37.0	0.5962	0.12
24.5	27 24.85	26 25 50.5	0.6005	
26.5	11 29 14.97	+26 7 5.6	0.6048	0.12

My observation of 1899 March 5, gives the following corrections: O−C, $\Delta\alpha = -1^s.55$, $\Delta\delta = +13''.9$.

Mt. Hamilton, 1899 *March* 10.

OBSERVATIONS OF COMET a 1899,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

BY WILLIAM J. HUSSEY.

1899 Mt. Hamilton M.T.	✱	No. Comp.	☄ − ✱ $\Delta\alpha$	☄ − ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			m s	′ ″	h m s	° ′ ″		
March 4 7 8 44	1	8 , 8	−0 26.37	−1 11.3	3 48 3.75	−27 8 1.7	9.454	0.870
7 22 35	2	3	. . . .	−3 39.4	. . . .	−27 7 6.5	. .	0.863
7 41 10	2	8	+3 55.88	. . . .	3 47 55.62	. . . .	9.537	. .
5 7 26 13	3	9 , 8	−0 12.96	+3 31.4	3 42 12.56	−25 36 53.8	9.519	0.852
6 7 32 47	4	8 , 8	−0 7.90	−3 53.6	3 36 44.53	−21 8 32.2	9.548	0.840

Mean Places for 1899.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	3 48 29.16	+0.96	−27 6 42.0	−8.4	C.DM. −27°1433 connected with ✱2
2	3 43 58.80	+0.94	−27 3 18.9	−8.2	Gould, Zone Catal. 1298
3	3 42 24.58	+0.94	−25 40 17.4	−7.8	Gould, Gen. Catal. 4188
4	3 36 51.51	+0.92	−24 4 31.5	−7.1	C.DM. −24°1815 connected with ✱5
5	3 37 38.72	+0.95	−23 58 3.3	−7.1	Gould ½ (Gen. Catal. 4081 + Zone Catal. 1092)

ELEMENTS OF COMET a 1899 (SWIFT),

BY WILLIAM J. HUSSEY.

From my observations of March 4, 5, and 6, I have obtained the following elements of the orbit of this comet. According to these elements the comet will again be visible after passing the sun, and from May will be in good position for observation at northern observatories.

ELEMENTS.

$$T = 1899 \text{ April } 13.26427 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 4^\circ\ 54'\ 14''.4 \\ \Omega &= 23\ \ \ 8\ \ 45.2 \\ i &= 146\ \ \ 3\ \ 42.6 \end{aligned}\right\} 1899.0$$

$$\log q = 9.537504$$

O − C:

$$\Delta\lambda \cos\beta = +3''.0 \quad , \quad \Delta\beta = -4''.9$$

CONSTANTS FOR THE EQUATOR 1899.0.

$$x = r(9.989282) \sin(v + 75^\circ\ 22'\ 35''.6)$$
$$y = r(9.995654) \sin(v + 163\ 32\ 37.9)$$
$$z = r(9.416172) \sin(v + 41\ 46\ 33.0)$$

NOTES ON THE PROBLEM OF THE SUN'S MEAN TEMPERATURE,

BY SIMON NEWCOMB.

Dr. CHESSIN's remark in *A.J.* 456 does not seem to me well founded. The problem is this: The parts of a spherical gaseous mass A are kept in equilibrium between the force of their mutual gravitation, and of their elasticity due to temperature. To preserve this equilibrium let there be an absolute temperature T_0, which may increase from the surface to the center. Now, by the radiation of heat let the radius of the mass A contract from R_0 to R. What is the temperature T necessary to maintain the equilibrium of the mass after contraction? The formula given by SEE,

$$T = \frac{R_0 T_0}{R}$$

does not seem open to doubt. I do not see how hydrodynamic laws enter into the question.

BY A. S. CHESSIN.

With regard to Prof. NEWCOMB's remark, I beg to observe that I did not raise the question as to whether the law which Dr. SEE calls *his* (and which, more correctly, should be called RITTER's, who expressed it in 1881 — as Dr. SEE states himself), was at all plausible or not. I simply objected to Dr. SEE's *derivation*, in the course of which, as I have stated before, he assumes that which he wants to prove.

As to neglecting the principles of hydrodynamics it suffices to point out, for example, the inadmissible assumption of uniform density throughout a gaseous body in dynamical condition (*v.l.* contraction and radiation).

SUNSPOT OBSERVATIONS, JANUARY–JUNE, 1898,

MADE WITH THE 4½-INCH EQUATORIAL OF THE LEANDER McCORMICK OBSERVATORY, UNIVERSITY OF VIRGINIA,

BY J. ADAIR LYON.

1898	Time Obs.	Totals Gps.	Totals Spots	Fac. Gps.	Condition of Sky	1898	Time Obs.	Totals Gps.	Totals Spots	Fac. Gps.	Condition of Sky	1898	Time Obs.	Totals Gps.	Totals Spots	Fac. Gps.	Condition of Sky
Jan. 1	1	3	5	2	clear	Feb. 24	4	2	3	0	hazy	April 18	1	0	0	1	hazy
3	1	3	4	1	clear	25	2	2	3	3	cloudy	20	1	0	0	0	clear
4	1	4	9	1	hazy	26	1	2	8	2	clear	21	1	0	0	0	clear
20	4	5	9	1	hazy	28	2	2	5	1	hazy	29	2	2	7	1	cloudy
21	2	5	14	1	clear	Mar. 1	1	2	6	1	clear	30	0	3	10	1	clear
23	3	3	12	0	hazy	3	3	2	6	1	hazy	May 3	3	0	0	2	hazy
24	4	3	16	2	clear	5	1	4	12	3	clear	4	2	0	0	0	hazy
26	2	1	7	0	hazy	7	1	5	20	1	hazy	10	2	2	12	1	clear
27	4	1	7	1	hazy	8	0	5	38	1	clear	12	0	1	7	1	clear
28	2	1	5	2	clear	9	2	5	32	1	clear	14	0	2	5	2	hazy
29	0	1	2	2	clear	10	3	4	12	0	cloudy	17	3	2	2	2	hazy
Feb. 1	1	0	0	1	clear	14	1	3	32	1	clear	24	0	2	2	2	clear
3	0	1	2	1	clear	17	2	2	4	2	hazy	28	1	1	2	2	clear
4	4	2	6	1	hazy	19	1	0	0	1	hazy	31	0	1	5	0	clear
5	0	2	5	1	cloudy	26	1	0	0	0	hazy	June 2	2	1	2	1	clear
9	2	5	16	3	clear	31	1	1	1	0	cloudy	4	1	0	0	2	hazy
10	0	4	15	3	clear	April 1	1	1	2	1	clear	6	0	1	3	1	clear
11	3	3	17	1	hazy	2	0	1	2	1	hazy	7	2	0	0	0	clear
12	0	3	20	1	clear	3	2	1	3	1	clear	10	1	0	0	0	clear
13	3	1	14	0	cloudy	6	1	1	6	0	clear	11	1	0	0	0	hazy
14	2	3	25	3	clear	8	1	2	8	0	clear	12	0	0	0	0	clear
15	0	4	18	2	hazy	11	0	1	1	2	clear	22	1	1	1	2	clear
16	4	3	12	1	hazy	12	1	0	0	0	hazy	23	0	1	1	2	clear
23	3	2	4	0	cloudy	17	3	0	0	0	hazy	27	3	2	3	1	clear

On the dates omitted, clouds prevented any observations. The small number of spots for the last three months, as compared with the first three, is very apparent.

Charlottesville, 1898 *Nov.* 1.

NEW ASTEROIDS.*

Communicated by Prof. KREUTZ.

			M.T.		α	δ	Daily Motion	Discoverer
ED	11^{M}	Dec. 9	8^{h} 59^{m}.0	Nice	4^{h} 43^{m} 0^{s}	+22° 41′	−56^{s} − 5′	Charlois (Dec. 8)
EE	11.0	Feb. 15	10 5.0	Heidelberg	9 54 28	+15 0	−60 +12	Wolf–Schwassman
EF	11.0	Feb. 17	12 20.7	"	10 18 0	+ 7 14	+64 + 6	" "

NOTICE.*

Communication Concerning the Publication of an Annual Astronomical Report.

I intend to publish an *Astronomischer Jahresbericht mit Unterstützung der Astronomischen Gesellschaft.* It will give short reports of all the works on astronomy, astrophysics and geodesy, both practical and theoretical, which have appeared during the year. The first volume will appear in 1900, and will contain reports of all the publications of 1899. Not wishing to overlook anything, I should be much obliged if all authors of such publications, appearing as single books or articles in journals not usually destined and used for astronomical publications, would kindly communicate them to me.

WALTER F. WISLICENUS, Ph.D.,
Professor at the University.

Strassburg, (*Elsass*) *Nicolausring* 37, 1899 *January*.

* *From Supplement to Astronomical Journal*, No. 457.

CONTENTS.

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THE

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FOUNDED BY B. A. GOULD.

No. 459.

VOL. XX. BOSTON, 1899 APRIL 8. NO. 3

OBSERVATIONS OF COMET 1898 I,

MADE AT THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA,

BY C. D. PERRINE.

1898 Mt. Hamilton M.T.		*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Mar. 26	16 7 31	1	12 , 7	+1 8.62	+1 29.4	21 44 59.26	+23 56 12.4	n9.701	0.645
27	15 21 24	2	d10 , 8	−0 21.58	+3 21.5	21 48 50.35	+24 55 19.1	n9.714	0.689
28	16 52 52	3	d10 , 8	−0 17.32	−3 20.0	21 53 7.81	+25 59 45.9	n9.686	0.563
29	16 41 32	4	10 , 8	−1 2.78	−8 1.5	21 57 11.30	+26 59 55.6	n9.697	0.569
30	16 44 3	5	10 , 8	−1 25.93	+2 35.2	22 1 20.13	+27 59 6.2	n9.700	0.556
Apr. 2	15 30 21	6	12 , 8	+0 50.79	−1 27.1	22 13 51.91	+30 50 57.6	n9.737	0.654
3	15 38 46	7	10 , 8	−1 45.32	−7 38.6	22 18 15.23	+31 48 8.9	n9.741	0.635
4	15 45 11	8	10 , 8	+1 0.36	−7 52.1	22 22 41.45	+32 44 28.4	n9.746	0.622
6	15 58 6	9	d11 , 8	−0 29.61	−2 0.7	22 31 43.46	+34 34 21.6	n9.753	0.588
7	15 44 54	10	10 , 8	−0 54.00	−6 18.2	22 36 16.34	+35 27 14.8	n9.760	0.609
8	16 19 7	11	d10 , 8	+0 10.01	−1 50.4	22 41 0.88	+36 20 50.5	n9.752	0.519
10	16 14 42	12	d10 , 8	−0 10.73	−0 42.5	22 50 26.72	+38 2 10.4	n9.768	0.531
11	15 59 33	14	d10 , 8	−0 31.75	+1 31.8	22 55 11.88	+38 50 49.5	n9.777	0.559
12	16 10 39	16	10 , 8	−0 53.01	+6 55.3	23 0 5.26	+39 39 13.8	n9.780	0.529
13	15 21 26	17	8 , 7	+1 22.52	−3 57.4	23 4 49.61	+40 24 32.0	n9.790	0.633
15	15 27 24	18	10 , 6	−2 38.49	+0 0.5	23 14 48.36	+41 55 0.5	n9.799	0.618
16	16 11 57	19	12 , 8	+1 8.64	+3 51.9	23 20 0.43	+42 39 43.5	n9.801	0.508
17	15 28 9	20	d10 , 8	+0 1.11	−2 8.3	23 24 57.25	+43 20 33.3	n9.810	0.613
18	15 34 51	21	16 , 8	−1 28.99	+0 51.3	23 30 7.07	+44 1 38.9	n9.815	0.595
19	15 38 20	22	2	. . . .	+4 49.5	. . . .	+44 11 20.6	. . .	0.591
20	15 37 57	23	11 , 8	+1 45.52	−2 4.5	23 40 32.12	+45 19 45.2	n9.825	0.587
20	16 30 30	24	10 , 6	+1 44.55	−0 57.2	23 40 43.42	+45 21 9.2	n9.815	0.433
21	15 25 50	25	16 , 8	−2 1.09	+1 7.6	23 45 44.64	+45 56 36.1	n9.828	0.620
22	15 19 9	26	d10 , 8	+0 4.18	−8 43.9	23 51 0.57	+46 32 18.6	n9.833	0.629
23	15 12 32	27	16 , 8	−1 28.02	−2 33.5	23 56 18.33	+47 6 46.4	n9.834	0.643
24	14 58 54	28	d10 , 8	+0 17.40	−6 26.9	0 1 36.17	+47 39 50.3	n9.833	0.669
25	15 2 20	29	d10 , 8	+0 17.66	+5 23.3	0 6 59.84	+48 12 4.0	n9.839	0.678
26	15 7 41	30	16 , 8	+2 1.31	−2 12.3	0 12 25.17	+48 43 3.6	n9.845	0.651
28	15 26 54	31	16 , 8	−1 52.17	−0 18.2	0 23 20.67	+49 41 33.4	n9.858	0.611
28	15 26 54	32	16 . 8	−2 8.39	+0 7.0	0 23 20.68	+49 41 31.5	n9.858	0.611
29	14 55 30	33	12 , 7	−2 43.38	+0 15.0	0 28 40.46	+50 8 9.4	n9.850	0.683
May 1	16 1 53	34	1	. . . .	+1 2.3	. . . .	+51 0 10.0	. . .	0.494
1	16 4 55	34	d 2	−0 39.98	. . . .	0 39 52.05	. . . .	n9.873	. .
2	15 56 28	35	12 . 8	+1 32.23	+0 16.6	0 45 17.82	+51 23 42.9	n9.876	0.533
3	15 57 47	36	16 , 8	−0 10.16	+4 55.6	0 50 45.83	+51 46 14.4	n9.880	0.526
4	15 43 51	37	d10 . 8	+0 15.18	+4 1.0	0 56 9.86	+52 7 27.1	n9.882	0.573
5	14 39 34	39	12 . 8	−2 33.91	+0 31.7	1 1 22.62	+52 26 50.5	n9.856	0.723
6	15 31 3	40	d10 . 8	−0 7.21	−0 17.0	1 7 0.58	+52 46 19.2	n9.886	0.604
8	14 41 57	42	18 . 9	−1 10.85	−2 57.8	1 17 10.06	+53 21 35.1	n9.866	0.718
9	15 50 43	43	d10 . 8	+0 15.41	−3 11.8	1 23 17.59	+53 38 30.6	n9.898	0.563
9	16 9 14	44	d 8 , 7	−0 38.76	+1 27.6	1 23 21.88	+53 38 43.4	n9.899	0.504

1898 Mt. Hamilton M.T.		*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
May 10	15 41 29	45	12 , 8	+2 35.01	−3 54.5	1 28 37.43	+53 53 37.3	n9.898	0.590
11	14 16 46	46	d10 , 8	+0 50.90	+2 6.9	1 33 38.04	+54 7 3.1	n9.816	0.770
11	14 48 57	47	14 , 9	+2 0.98	+3 11.1	1 33 45.26	+54 7 21.2	n9.874	0.713
13	15 49 32	48	11 , 10	−0 45.01	−4 53.4	1 44 32.49	+54 33 41.7	n9.906	0.573
16	14 23 49	49	14 , 8	+1 37.59	−2 36.8	1 59 47.73	+55 5 27.7	n9.856	0.766
19	14 21 54	50	16 , 8	+1 20.04	+4 28.3	2 14 57.59	+55 30 55.7	n9.856	0.772
19	14 50 9	51	d10 , 8	−0 11.79	+8 17.5	2 15 3.36	+55 31 4.9	n9.883	0.723
20	14 59 48	52	d10 , 8	−0 44.10	+2 58.8	2 20 2.85	+55 38 10.0	n9.890	0.707
20	15 20 52	53	4	. . . .	−0 13.4	. . . .	+55 38 17.7	. . .	0.662
20	15 31 15	53	11	+1 20.96	. . . .	2 20 8.88	. . . .	n9.908	. .
25	14 42 50	54	5	. . . .	−4 13.6	. . . .	+56 3 57.4	. . .	0.746
25	14 57 38	54	16	+2 10.31	. . . .	2 41 0.04	. . . .	n9.890	. .
28	14 55 10	55	3	. . . .	−5 34.5	. . . .	+56 12 46.4	. . .	0.725
29	14 19 12	56	d10 , 8	−0 49.35	+0 16.2	3 1 59.90	+56 14 45.0	n9.852	0.787
29	14 37 2	57	d10 , 8	+1 13.34	−0 40.0	3 2 2.92	+56 14 50.7	n9.872	0.759
June 2	15 7 35	58	d 8 , 8	+0 33.57	−0 21.3	3 19 16.43	+56 18 31.0	n9.898	0.704
3	14 58 12	60	d10 , 8	+0 1.36	+8 3.0	3 23 23.28	+56 18 34.7	n9.890	0.723
4	15 32 49	62	8 , 4	−2 13.03	−6 1.0	3 27 33.00	+56 18 5.7	n9.913	0.649
5	15 10 22	63	14 , 8	+1 43.24	−6 42.7	3 31 29.31	+56 17 23.9	n9.899	0.699
6	14 46 31	64	18 , 8	+0 55.33	+7 37.6	3 35 22.43	+56 16 25.6	n9.880	0.744
7	14 39 35	65	d10 , 8	+0 34.69	+0 55.6	3 39 14.26	+56 15 9.8	n9.873	0.757
8	14 31 50	66	d10 , 8	−0 34.34	−0 47.0	3 43 3.05	+56 13 33.3	n9.865	0.770
9	14 44 57	68	d10 , 8	−0 27.89	−0 29.6	3 46 50.63	+56 11 45.0	n9.877	0.747
10	15 5 12	69	d10 , 8	−0 27.44	−7 13.5	3 50 35.68	+56 9 39.4	n9.895	0.708
11	14 54 7	70	d10 , 8	−0 18.03	+1 22.3	3 54 13.07	+56 7 22.0	n9.885	0.733
11	15 26 48	71	d10 , 8	+0 1.26	+3 6.8	3 54 18.13	+56 7 19.5	n9.908	0.662
12	15 1 4	72	10 , 6	−3 27.18	−4 46.4	3 57 49.85	+56 4 52.3	n9.891	0.718
14	14 29 51	73	d10 , 8	−0 33.22	+3 19.8	4 4 45.47	+55 59 17.8	n9.863	0.770
17	14 27 17	74	10 , 6	−1 58.50	−1 23.4	4 14 50.76	+55 49 37.2	n9.860	0.772
19	14 56 43	75	10 , 6	−2 3.48	+2 31.6	4 21 21.67	+55 42 21.0	n9.886	0.719
20	14 4 33	76	d10 , 8	+0 58.49	−1 4.9	4 24 23.68	+55 38 44.4	n9.832	0.805
20	14 18 22	77	d 8 , 6	−0 56.22	+1 52.7	4 24 25.77	+55 38 27.0	n9.848	0.784
22	15 2 47	78	14 , 8	−0 58.66	−1 29.1	4 30 39.83	+55 30 42.1	n9.892	0.702
23	14 59 20	79	10 , 6	−2 5.34	+5 55.8	4 33 39.28	+55 26 36.5	n9.889	0.708
24	14 20 44	80	d10 , 8	+0 46.17	+1 53.0	4 36 30.81	+55 22 33.6	n9.853	0.775
25	14 56 3	81	8 , 6	+3 43.79	−2 28.2	4 39 28.46	+55 18 12.3	n9.886	0.710
26	14 28 41	82	10 , 8	−0 55.08	+2 21.6	4 42 16.38	+55 13 55.0	n9.862	0.758
27	14 31 9	83	10 , 8	−1 40.20	+4 5.8	4 45 4.11	+55 9 33.5	n9.865	0.754
28	14 57 50	84	10 , 8	+1 7.71	−0 28.7	4 47 52.07	+55 4 58.9	n9.887	0.702
July 1	15 4 14	85	d10 , 8	−0 29.45	+0 37.9	4 55 51.68	+54 51 17.4	n9.891	0.681
9	15 4 17	86	10 , 6	+2 14.47	+5 2.2	5 15 14.91	+54 13 48.2	n9.893	0.651
10	15 6 24	87	10 , 6	+4 29.34	+0 18.6	5 17 29.81	+54 9 4.5	n9.891	0.648
11	14 31 16	88	12 , 6	−1 31.13	+0 26.1	5 19 39.11	+54 4 29.8	n9.871	0.720
12	14 24 27	89	16 , 8	+0 38.62	−4 18.2	5 21 48.89	+53 59 45.3	n9.866	0.730
16	14 35 54	90	d10 , 8	−0 22.59	−1 4.6	5 30 7.88	+53 41 3.3	n9.877	0.695
17	14 38 25	93	10 , 7	+1 23.14	+6 6.0	5 32 6.39	+53 36 30.0	n9.878	0.688
17	14 57 37	94	d10 , 8	+0 19.42	+8 35.3	5 32 9.23	+53 36 27.6	n9.889	0.641
18	14 10 0	95	d10 , 8	−0 3.34	+4 18.0	5 34 1.77	+53 32 1.6	n9.859	0.737
18	14 34 25	96	d10 , 8	−0 8.70	+2 34.0	5 34 3.61	+53 31 56.1	n9.876	0.690
19	14 28 48	97	10 , 6	+1 46.12	−1 59.6	5 35 58.46	+53 27 22.5	n9.874	0.702
19	14 52 57	98	10 , 6	+1 54.94	−0 26.1	5 36 0.09	+53 27 17.4	n9.886	0.644
22	15 8 13	99	12 , 8	−1 13.22	+2 32.1	5 41 33.80	+53 13 50.7	n9.892	0.590
23	14 43 58	100	d 8 , 6	+0 31.92	−1 45.3	5 43 18.96	+53 9 33.1	n9.884	0.645
23	15 4 30	100	10 , 6	+0 33.34	−1 49.5	5 43 20.38	+53 9 28.9	n9.890	0.595
25	15 19 45	101	d10 , 8	−0 40.29	+3 19.6	5 46 49.40	+53 0 47.8	n9.892	0.539
26	15 2 53	102	d10 , 7	+0 8.22	+1 16.4	5 48 29.59	+52 56 32.7	n9.889	0.583
27	15 28 39	103	10 , 8	+0 59.93	+1 10.7	5 50 9.34	+52 52 11.0	n9.891	0.498
28	15 27 29	104	d10 , 8	+0 34.19	+7 6.8	5 51 47.75	+52 48 2.3	n9.890	0.496
29	15 15 48	105	12 , 8	+0 40.21	+1 55.1	5 53 21.54	+52 43 58.0	n9.890	0.526
30	14 56 46	106	d10 , 8	+0 20.69	+0 26.7	5 54 53.74	+52 39 57.7	n9.887	0.577

1898 Mt. Hamilton M.T.		*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Aug. 12	14 17 4	107	10 , 8	−1 47.81	+1 59.8	6 12 21.39	+51 52 24.9	n9.878	0.599
13	15 17 2	108	10 , 8	0 37.00	−1 22.3	6 13 32.24	+51 49 2.7	n9.875	0.391
14	15 4 5	109	12 , 8	+1 30.34	−0 6.7	6 14 38.68	+51 45 52.3	n9.877	0.431
20	15 19 24	110	10 , 8	−1 10.84	+1 54.8	6 20 41.15	+51 28 27.0	n9.864	0.290
21	15 31 28	111	10 , 8	−0 16.36	−0 46.0	6 21 35.97	+51 25 46.0	n9.855	0.204
24	15 17 54	112	10 , 8	−0 6.11	+0 35.7	6 24 7.08	+51 18 13.9	n9.857	0.230
26	15 27 27	113	10 , 8	−0 47.97	+3 28.4	6 25 39.62	+51 13 35.2	n9.841	0.134
27	15 31 38	114	d10 , 8	−0 4.52	+1 14.9	6 26 23.12	+51 11 21.6	n9.839	0.083
Sept. 9	16 22 48	115	10 , 8	−1 16.53	+5 11.5	6 32 59.23	+50 48 36.1	n9.704	n9.792
10	15 34 8	116	10 , 8	−0 59.79	+4 0.0	6 33 16.02	+50 47 24.9	n9.780	9.279
16	15 16 27	117	d10 , 8	+0 3.22	−2 12.6	6 34 16.38	+50 41 1.2	n9.772	9.041
16	15 35 22	118	d10 , 8	+0 0.31	−2 23.6	6 34 16.36	+50 41 1.0	n9.742	n9.398
17	15 17 6	119	d10 , 8	+0 6.04	−3 7.2	6 34 19.24	+50 40 6.5	n9.768	8.301
17	15 27 23	120	d10 , 8	+0 3.06	−3 18.3	6 34 19.15	+50 40 6.2	n9.737	n9.230
17	15 40 40	121	d10 , 8	−0 20.75	−3 5.2	6 34 19.07	+50 40 4.3	n9.727	n9.602
18	14 4 45	122	d10 , 8	+0 6.73	−3 52.5	6 34 19.97	+50 39 21.1	n9.839	0.155
18	14 17 39	123	d10 , 8	+0 3.67	−4 5.4	6 34 19.80	+50 39 19.0	n9.830	0.061
18	14 34 19	124	d10 , 8	−0 20.24	−3 49.9	6 34 19.63	+50 39 19.5	n9.815	9.914
Oct. 8	12 30 43	125	d10 , 8	+0 5.34	+0 3.5	6 26 57.35	+50 28 15.9	n9.844	0.212
14	13 50 19	127	d10 , 8	−0 7.41	+2 21.2	6 21 40.74	+50 24 8.5	n9.708	n9.699
16	13 6 51	129	d10 , 8	+0 0.92	+1 23.8	6 19 39.45	+50 22 12.7	n9.765	8.845
19	15 51 6	130	d10 , 8	−0 5.34	−2 32.0	6 16 7.59	+50 18 33.4	n8.964	n0.294
Nov. 6	10 59 51	132	d10 , 8	−0 7.40	+2 37.3	5 49 44.40	+49 31 7.8	n9.779	9.672
7	12 18 54	134	d10 , 8	−0 13.48	−1 28.2	5 47 52.86	+49 26 28.0	n9.614	n9.964
8	12 50 21	135	d10 , 8	+0 1.48	+3 46.1	5 46 4.08	+49 21 37.0	n9.493	n0.130
11	12 2 6	137	d18 , 12	+0 7.54	−0 5.1	5 40 42.55	+49 6 16.3	n9.595	n0.017
12	12 2 3	139	d10 , 8	+0 6.05	−4 26.8	5 38 52.45	+49 0 33.1	n9.574	n0.009
13	12 12 2	140	d10 , 9	−0 8.60	−1 12.8	5 36 59.79	+48 54 42.6	n9.522	n0.076
15	11 54 16	141	d10 , 10	−0 15.54	+0 53.6	5 33 12.91	+48 40 36.7	n9.544	n0.033

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 13 50.28	+0.36	+23 54 48.8	−5.8	Becker, Berlin A.G. 8409
2	21 19 11.58	+0.35	+24 52 0.5	−5.6	" " " 8446
3	21 53 24.79	+0.34	+26 3 11.1	−5.5	Rogers, Camb. A.G. Catal. 13050
4	21 58 13.75	+0.33	+27 8 2.4	−5.3	" " " " 13132
5	22 2 45.74	+0.32	+27 56 36.2	−5.2	" " " " 13203
6	22 13 0.84	+0.28	+30 52 29.8	−5.1	Leiden A.G. Zones, 3, 4
7	22 20 0.30	+0.25	+31 55 52.3	−4.8	" " " 7, 9
8	22 21 40.83	+0.26	+32 52 25.5	−5.0	" " " 98, 103
9	22 32 12.86	+0.21	+34 36 26.8	−4.5	" " " 89, 93
10	22 37 10.15	+0.19	+35 33 37.3	−4.3	Lund A.G. Zones 289, 329
11	22 40 50.68	+0.19	+36 22 45.1	−4.2	" " " " "
12	22 50 37.26	+0.19	+38 2 57.0	−4.1	Micrometer-comparison with *13
13	22 48 12.95	+0.18	+38 4 27.2	−3.9	Lund A.G. Zones 345, 347
14	22 55 43.46	+0.17	+38 49 21.3	−3.6	Micrometer-comparison with *15
15	22 52 53.91	+0.18	+38 50 36.4	−3.7	Lund A.G. Zones 44, 47, 60
16	23 0 58.10	+0.17	+39 32 21.7	−3.2	" " " 44, 47
17	23 3 26.93	+0.16	+40 28 32.6	−3.2	Bonn A.G. Catal. 17471
18	23 17 26.72	+0.13	+41 55 2.5	−2.5	" " " 17702
19	23 18 51.66	+0.13	+42 35 54.2	−2.6	" " " 17727
20	23 24 56.03	+0.11	+43 22 44.0	−2.4	" " " 17839
21	23 31 35.96	+0.10	+44 0 49.7	−2.1	" " " 17950
22	23 37 14.37	+0.09	+44 56 32.9	−1.8	" " " 18074
23	23 38 46.52	+0.08	+45 21 51.6	−1.9	" " " 18093

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
24	23 38 58.79	+0.08	+45 22 8.3	−1.9	Bonn A.G. Catal. 18095
25	23 47 45.65	+0.08	+45 55 29.9	−1.4	“ “ “ 18231
26	23 50 56.31	+0.08	+46 11 3.9	−1.1	“ “ “ 18284
27	23 57 46.27	+0.08	+47 9 20.9	−1.0	“ “ “ 18407
28	0 1 18.68	+0.09	+47 46 18.1	−0.9	“ “ “ 3
29	0 6 42.08	+0.10	+48 6 11.4	−0.7	“ “ “ 91
30	0 10 23.75	+0.11	+48 45 46.4	−0.5	“ “ “ 155
31	0 25 12.73	+0.11	+49 41 51.4	+0.2	“ “ “ 376
32	0 25 28.96	+0.11	+49 41 24.3	+0.2	“ “ “ 383
33	0 31 23.73	+0.11	+50 7 54.0	+0.4	⅓(Bonn A.G. 465+2 Harvard 260)
34	0 40 31.92	+0.11	+50 59 7.1	+0.6	Rogers, Camb. A.G. Catal. 329
35	0 43 45.47	+0.12	+51 23 25.7	+0.6	“ “ “ “ 359
36	0 51 25.86	+0.13	+51 41 17.9	+0.9	“ “ “ “ 425
37	0 55 54.54	+0.14	+52 3 22.1	+1.0	Micrometer-comparison with *38
38	0 58 2.60	+0.15	+51 57 22.8	+1.2	Rogers, Camb. A.G. Catal. 486
39	1 3 56.37	+0.16	+52 26 17.4	+1.4	“ “ “ “ 528
40	1 7 7.64	+0.18	+52 47 34.8	+1.4	Micrometer-comparison with *41
41	1 2 0.14	+0.18	+52 44 27.1	+1.1	Rogers, Camb. A.G. Catal. 516
42	1 18 50.68	+0.23	+53 24 31.1	+1.8	“ “ “ “ 634
43	1 23 1.92	+0.26	+53 41 43.4	+2.0	“ “ “ “ 661
44	1 24 0.38	+0.26	+53 37 13.8	+2.0	“ “ “ “ 673
45	1 26 2.14	+0.28	+53 57 29.8	+2.0	“ “ “ “ 683
46	1 32 46.83	+0.31	+54 4 53.9	+2.3	“ “ “ “ 738
47	1 31 43.97	+0.31	+54 4 7.9	+2.2	“ “ “ “ 726
48	1 45 17.15	+0.35	+54 38 32.5	+2.6	“ “ “ “ 854 [A.G. 1840)
49	1 58 9.74	+0.40	+55 8 1.8	+2.7	½ (Rogers, Camb. A.G. Cat. 965+Helsingfors-Gotha
50	2 13 37.06	+0.49	+55 26 24.5	+2.9	Helsingfors-Gotha A.G. Catal. 2126
51	2 15 14.65	+0.50	+55 22 44.4	+3.0	“ “ “ “ 2168
52	2 20 46.42	+0.53	+55 35 8.1	+3.1	“ “ “ “ 2254
53	2 18 47.39	+0.53	+55 38 28.1	+3.0	“ “ “ “ 2226
54	2 41 49.03	+0.70	+56 8 7.8	+3.2	“ “ “ “ 2528
55	2 57 52.53	+0.78	+56 18 17.5	+3.4	“ “ “ “ 2737
56	3 2 48.43	+0.82	+56 14 25.3	+3.5	“ “ “ “ 2799
57	3 0 48.77	+0.81	+56 15 27.4	+3.3	“ “ “ “ 2770
58	3 18 41.92	+0.94	+56 18 49.2	+3.1	Micrometer-comparison with *59
59	3 16 22.21	+0.94	+56 18 51.9	+3.0	Helsingfors-Gotha A.G. Catal. 2962
60	3 23 20.93	+0.99	+56 10 28.6	+3.1	Micrometer-comparison with *61
61	3 23 58.41	+0.99	+56 5 31.2	+3.1	Helsingfors-Gotha A.G. Catal. 3037
62	3 29 45.00	+1.03	+56 24 3.6	+3.1	“ “ “ “ 3098
63	3 29 45.00	+1.07	+56 24 3.6	+3.0	“ “ “ “ 3098
64	3 34 25.98	+1.12	+56 8 45.0	+3.0	“ “ “ “ 3154
65	3 38 38.42	+1.15	+56 14 11.2	+3.0	“ “ “ “ 3190
66	3 43 36.21	+1.18	+56 14 17.3	+3.0	Micrometer-comparison with *67
67	3 47 17.30	+1.18	+56 12 11.6	+3.1	Helsingfors-Gotha A.G. Catal. 3269
68	3 47 17.30	+1.22	+56 12 11.6	+3.0	“ “ “ “ 3269
69	3 51 1.88	+1.24	+56 16 50.0	+2.9	“ “ “ “ 3295
70	3 54 29.84	+1.26	+56 5 56.9	+2.8	“ “ “ “ 3327
71	3 54 15.61	+1.26	+56 4 9.9	+2.8	“ “ “ “ 3325
72	4 1 15.74	+1.29	+56 9 35.9	+2.8	“ “ “ “ 3395
73	4 5 17.35	+1.34	+56 2 35.1	+2.5	“ “ “ “ 3428
74	4 16 47.81	+1.45	+55 50 58.5	+2.1	“ “ “ “ 3528
75	4 23 23.62	+1.53	+55 39 47.4	+2.0	“ “ “ “ 3584
76	4 23 23.62	+1.57	+55 39 47.4	+1.9	“ “ “ “ 3584
77	4 25 20.43	+1.56	+55 36 32.4	+1.9	“ “ “ “ 3609
78	4 31 36.91	+1.58	+55 32 9.5	+1.7	“ “ “ “ 3665
79	4 35 42.97	+1.65	+55 20 39.1	+1.6	“ “ “ “ 3708
80	4 35 42.97	+1.67	+55 20 39.1	+1.5	“ “ “ “ 3708
81	4 35 42.97	+1.70	+55 20 39.1	+1.4	“ “ “ “ 3708
82	4 43 9.74	+1.72	+55 11 32.1	+1.3	½ (Hels.-Gotha A.G. Catal. 3773+Rogers 1975)
83	4 46 42.58	+1.73	+55 5 26.6	+1.1	½ (Hels.-Gotha A.G. Catal. 3795+Rogers 2000)

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
84	4 46 42.58	+1.78	+55 5 26.6	+1.0	½ (Hels.-Gotha A.G. Catal. 3795 + Rogers 2000)
85	4 56 19.25	+1.88	+54 50 39.0	+0.5	Rogers, Camb. A.G. Catal. 2057
86	5 12 58.31	+2.13	+54 8 46.4	−0.4	" " " " 2146
87	5 12 58.31	+2.16	+54 8 46.4	−0.5	" " " " 2146
88	5 21 8.07	+2.17	+54 4 4.4	−0.7	" " " " 2196
89	5 21 8.07	+2.20	+54 4 4.4	−0.9	" " " " 2196
90	5 30 28.13	+2.34	+53 42 9.4	−1.5	Micrometer-comparison with *91 and *92
91	5 31 13.78	+2.34	+53 48 28.9	−1.6	Rogers, Camb. A.G. Catal. 2250
92	5 31 14.53	+2.34	+53 48 36.6	−1.6	" " " " 2251
93	5 30 40.88	+2.37	+53 30 25.6	−1.6	" " " " 2245
94	5 31 47.44	+2.37	+53 27 53.9	−1.6	" " " " 2256
95	5 34 2.71	+2.40	+53 27 45.3	−1.7	" " " " 2268
96	5 34 9.90	+2.41	+53 29 23.9	−1.8	" " " " 2270
97	5 34 9.90	+2.44	+53 29 23.9	−1.8	" " " " 2270
98	5 34 2.71	+2.44	+53 27 45.3	−1.8	" " " " 2268
99	5 42 44.52	+2.50	+53 11 20.8	−2.2	" " " " 2315
100	5 42 44.52	+2.52	+53 11 20.8	−2.4	" " " " 2315
101	5 47 27.12	+2.57	+52 57 30.9	−2.7	" " " " 2342
102	5 48 18.77	+2.60	+52 55 19.2	−2.9	" " " " 2353
103	5 49 6.77	+2.64	+52 51 3.3	−3.0	" " " " 2357
104	5 51 10.88	+2.68	+52 40 58.7	−3.2	" " " " 2368
105	5 52 38.53	+2.80	+52 42 6.3	−3.4	Micrometer-comparison with *104
106*	5 54 30.29	+2.76	+52 39 34.5	−3.5	" " " "
107	6 14 6.06	+3.14	+51 50 30.5	−5.4	Rogers, Camb. A.G. Catal. 2478
108	6 14 6.06	+3.18	+51 50 30.5	−5.5	" " " " 2478
109	6 13 5.11	+3.23	+51 46 4.5	−5.5	" " " " 2472
110	6 21 48.91	+3.38	+51 26 38.5	−6.3	" " " " 2518
111	6 21 48.91	+3.42	+51 26 38.5	−6.5	" " " " 2518
112	6 24 9.66	+3.53	+51 17 15.05	−6.9	Tucker, L.O. Meridian Circle, D.M. +51°1204
113	6 26 23.98	+3.61	+51 10 14.0	−7.2	Rogers, Camb. A.G. Catal. 2542
114	6 26 23.98	+3.66	+51 10 14.0	−7.3	" " " " 2542
115	6 34 11.62	+4.14	+50 43 33.7	−8.8	Tucker, L.O. Meridian Circle
116	6 34 11.62	+4.19	+50 43 33.7	−8.8	" " " "
117	6 34 8.73	+4.43	+50 43 22.9	−9.1	" " " "
118	6 34 11.62	+4.43	+50 43 33.7	−9.1	" " " "
119	6 34 8.73	+4.47	+50 43 22.9	−9.2	" " " "
120	6 34 11.62	+4.47	+50 43 33.7	−9.2	" " " "
121	6 34 35.36	+4.46	+50 43 18.8	−9.3	" " " "
122	6 34 8.73	+4.51	+50 43 22.9	−9.3	" " " "
123	6 34 11.62	+4.51	+50 43 33.7	−9.3	" " " "
124	6 34 35.36	+4.51	+50 43 18.8	−9.4	" " " "
125	6 26 56.51	+5.50	+50 28 21.7	−9.3	Micrometer-comparison with *126
126	6 28 18.03	+5.49	+50 29 48.98	−9.5	Tucker, L.O. Merid. Circle, * is B.D. +50 1320
127	6 21 42.36	+5.79	+50 21 55.7	−8.4	Micrometer-comparison with *128
128	6 20 23.96	+5.79	+50 20 7.9	−8.4	Rogers, Camb. A.G. Catal. 2507
129	6 19 32.65	+5.88	+50 20 57.3	−8.4	Micrometer-comparison with *158
130	6 16 7.19	+5.74	+50 21 14.3	−8.9	" " " *131
131	6 15 10.40	+5.76	+50 27 32.7	−8.8	Rogers, Camb. A.G. Catal. 2481
132	5 49 41.88	+6.92	+49 28 33.4	−2.9	Micrometer-comparison with *133
133	5 53 26.95	+6.92	+49 29 6.8	−2.9	Bonn A.G. Catal. 4905
134	5 47 59.39	+6.95	+49 27 59.1	−2.9	Micrometer-comparison with *133
135	5 45 55.62	+6.98	+49 17 52.6	−2.0	" " " *136
136	5 43 44.13	+6.99	+49 18 34.5	−1.7	Bonn A.G. Catal. 4769
137	5 40 27.95	+7.06	+49 6 22.3	−0.9	Micrometer-comparison with *138
138	5 38 39.29	+7.07	+49 5 0.4	−0.6	Bonn A.G. Catal. 4699
139	5 38 39.29	+7.11	+49 5 0.4	−0.5	" " " "
140	5 37 1.33	+7.06	+48 56 25.6	−0.2	" " " 4687
141	5 33 21.26	+7.19	+48 39 42.4	+0.7	Micrometer-comparison with *142
142	5 38 53.46	+7.18	+48 36 11.6	−0.2	Bonn A.G. Catal. 4768

NOTES.

d indicates that Δa was measured directly with the micrometer.

Comet *b*. — The observations of April 8, 16, May 6, 13, 28, June 4, 11, 25, July 9, 10, 18, 23, 26, 30 and subsequently, were made with the 36-inch equatorial. All the others were made with the 12-inch equatorial.

Position angle of tail —

Pacific Stand. Time				Pacific Stand. Time			
	h	m	°		h	m	°
March 19	17	10	281.2	April 17	15	45	303.6
22	15	15	277.4	18	16	0	298.2
April 2	15	50	287.2	21	16	0	299.5
13	15	30	292.9	23	15	30	306.0

March 19th, Comet bright, equals a 6^M or 7^M star. The coma is about 2′ in diameter and has a bright condensation 10″ in diameter. There is a broad fan-shaped tail which can be traced for 1° in the 4-inch comet seeker. Comet becomes invisible in the twilight at $17^h 45^m$ P.St.T. with the 12-inch equatorial and power of 150. — 21st, Comet is just visible to naked eye. Comet ceased to be visible in the dawn at $17^h 45^m$ P.St.T. High north wind 50–60 miles per hour. — 22d, Nucleus quite sharp. — 26th, The 36-inch equatorial, using powers 270 and 520 showed a fan-shaped streamer or jet on s.f. side of the nucleus. — 28th, High north wind sways telescope some. Seeing poor. — 29th, Comet has very sharp stellar nucleus of 8^M. — *April* 2d, Comet seems fully as bright as at discovery. Nucleus and tail very distinct. — 3d, Comet bright and easy in moonlight. Tail can be traced for 10′. Nucleus quite distinct. — 4th, Comet fainter; nucleus not so sharp. — 6th, Comet easily seen, but moonlight cuts off some of the outer fainter nebulosity and the tail is scarcely visible. Nucleus seems quite sharp at times. Sky milky, seeing good. — 7th, Nucleus is sharp and about as bright as the comparison star of $9^M.1$. With power of 500 a distinct fan-shaped jet is to be seen in the head. With this power the nucleus is not quite as sharp as a star. — 10th, High north wind jars telescope. Seeing poor. — 11th, Nucleus fully as bright as comparison star ($9^M.3$). North wind shakes telescope. — 17th, Long slender tail visible with the 12-inch equatorial In the 6½-inch comet seeker the tail is fan-shaped and rather broad at the end. The nucleus is about $9^M.5$ and fairly sharp. The comet is just visible to the naked eye. — 19th, Observation stopped by clouds. — 21st, Nucleus sharp; $9\frac{1}{2}^M$ or a little fainter. The jet in the head can still be seen. With the 6½-inch comet seeker the nucleus seems to be about one-half a magnitude brighter than with the 12-inch equatorial. — 22d, Nucleus seems brighter. $9^M.0$ or brighter. — 23d, Comet just visible to naked eye. — 24th, Nucleus sharp and fully as bright as $9^M.5$. — 25th, High north wind disturbs telescope. — 26th, Nucleus sharp when seeing is best, $9\frac{1}{2}^M$. Wind disturbs telescope. — 29th, Clouds and a gusty wind interfere at times. — *May* 2d, Comet fainter than on April 29. Nucleus is not sharp although the seeing is fair. — 5th, Nucleus not brighter than 10^M. — 6th, 36-inch equatorial, power 520. Condensation in the head is bright, but can detect no stellar point, possibly owing to rather poor seeing. The jet s.f. the nucleus is very plain when seeing is best. — 8th, Comet seems considerably brighter than at time of last observation with 12-inch (May 5). — 10th, Nucleus pronounced. — 11th, Nucleus still visible but faint. — 13th, Some clouds, seeing poor. — 16th, Comet much fainter; coma 2′ in diameter. Nucleus fairly sharp, 11^M. Can trace some tail. Comet easily visible in finder. — 19th, Comet faint, nucleus of 11^M visible. — 20th, 25th and 28th, Clouds prevent a complete observation. — 29th, Comet has nucleus of about 11^M, which is sharp during intervals of best seeing. — *June* 2d, High north wind shakes telescope badly at times. There is a well-marked condensation and a nucleus can be seen at times. — 3d, Comet rather faint. Cannot see stellar nucleus. — 5th, Comet faint but can see a stellar nucleus of 11^M–12^M. Seeing good. — 6th, Nucleus is sharp, but faint. — 9th, Comet rather faint. Can detect nucleus at times, but it is faint, not brighter than $12\frac{1}{2}^M$ or 13^M. The coma is about 1′ in diameter. — 10th, Comet easy to measure. Nucleus pronounced when seeing is best. Seeing poor. — 11th, 36-inch equatorial, power 270. Nucleus 12^M–13^M. — 12th, Comet easy to measure. Nucleus distinct and 11^M–12^M. — 14th, Comet has a well-defined nucleus of 12^M. Coma 1′ diameter. — 17th, Comet is larger and the nucleus brighter than Comet *e*. — 19th, Comet not brighter than 10^M. — 22d, Nucleus is about 13^M. — 23d, Can still see a nucleus which is sharp but very faint. A tail ½° long can be seen with the 6½-inch comet seeker. The brightness of the whole comet is just about the same as that of Comet *e*, but the nebulosity about the nucleus is much less bright (intrinsically) than Comet *e*. — 25th, There is a nucleus to Comet *b*, 1″ or 2″ in diameter. The nebulosity surrounding the nucleus is weaker than in Comet *e*. — 28th, Comet faint, but the nucleus of 13^M or fainter is still visible. — *July* 1st, Comet faint. Can just detect nucleus. Very smoky. — 9th, 36-inch equatorial. Comet has a nucleus of 14^M. — 11th, Comet faint and rather hard to measure. — 12th, Comet faint and rather hard to measure. Can distinguish a very faint nucleus. — 16th, Comet faint and not easy to measure. Not brighter than 12^M. Can just detect a nucleus. — 17th, Comet not brighter than 12^M or $12\frac{1}{2}^M$. — 18th, 36-inch equatorial. Comet 1′ in diameter, $11\frac{1}{2}^M$ or 12^M. Nucleus of 14^M visible. — 22d, Comet $12\frac{1}{2}^M$ or 13^M. Can just detect the faintest possible trace of a nucleus. — 23d, Comet 12^M–13^M and has a nucleus of 14^M. — 26th, The comparison-star used in this observation, Σ 810 = Rogers 2353, is double. Position-angle 245°.0, distance 3″.21 from an observation with the 12-inch equatorial on July 26. The magnitudes are 9.4 and 9.8. As the brighter component was used in the comet measures and the catalogue place is the mean of the two, the mean place used in the reduction includes a correction of $+0^s.16$ in α and $+0''.7$ in δ. — 27th, Comet faint, $12\frac{1}{2}^M$ or 13^M. — 29th, Comet 13^M, nucleus 16^M. — *August* 12th, Comet 13^M 14^M; faint and not easy to measure. ½′ in diameter. Some haze. — 13th, Comet faint, 14^M. — 14th, Comet ¾′ or 1′ in diameter; sharp but faint nucleus of $16\frac{1}{2}^M$. — 20th, Comet 15^M. Very faint central condensation, ¾′ to 1′ diameter. — 21st, Comet fainter than last night, probably owing to proximity of stars. Comet round and condensed at center. — 24th, Comet 14^M. Just faintest possible nucleus. — 26th, Comet seems brighter than at last observation. — *September* 9th, Comet 16^M. Some moonlight. — 17th, Comet faint, 16^M; about 10″ in diameter. There are traces of a nucleus. — 18th, Comet $15\frac{1}{2}^M$ or 16^M. — *October* 8th, Comet very faint; difficult to measure. Sky not very pure. — 14th, Comet faint and difficult, $16\frac{1}{2}^M$. Seeing poor. Wind shaking telescope. — 19th, Comet 10″–15″ in diameter and faint. — *November* 6th, Comet very faint, $16\frac{3}{4}^M$; 10″ in diameter; slightly brighter at the middle. — 7th, High north wind. Some faint stars near. — 8th, Comet $16\frac{1}{2}^M$–17^M. — 12th, Comet somewhat brighter and easier to measure, notwithstanding there is some smoke in the air. Some wind from the north sways telescope. — 13th, Comet very faint and difficult. Considerable haze. — 15th, Comet faint and difficult; near $16^M.5$ star. Comet $16\frac{1}{2}^M$–17^M.

The stars Rogers A.G. Catal., nos. 2577, 2580 and 2583 were used as comparison-stars on September 16, 17 and 18, as the comet was then almost stationary. A comparison of the resulting places showed a systematic deviation in declination of those places in which 2577 had been used. A deviation in right-ascension was noticed in the case of 2580. The intervals between the stars were measured with the 12-inch equatorial on November 1, and a discrepancy of about 5″ in δ was found in the case of 2577. There are four observations of this star in Rogers's zones in pairs one year apart, both sets agreeing well. There is also an observation of this star in B.B. VI. Following are the different results reduced to 1898.0:

	h m s	° ′ ″
B.B. VI. 1337	6 34 7.77	+50 43 40.2
Rogers A.G. 2577	8.60	28.9
Tucker, L.O. M.C. 1898	8.73	22.9

The Bonn observation is incomplete. From the Rogers and L.O. places it seems probable that the star has an annual proper motion of $-0''.25$ in δ. No safe conclusions can be drawn from the α positions.

Following are the places for 1898.0 of Rogers A.G 2580:

	h m s	° ′ ″
B.B. VI. 1338	6 34 11.63	+50 43 35.9
Rogers A.G. 2580	11.92	34.7
Tucker, L.O. M.C. 1898	11.62	33.7

Rogers A.G. 2583 was also reobserved by Professor Tucker, and the results are in good agreement with Rogers's and the Bonn places.

Professor Tucker has very kindly observed a number of comparison-stars with the meridian circle.

Mr. F. E. Ross, Fellow in Astronomy, has assisted in the observing work, especially with the 36-inch refractor and in the checking of some of the reductions. Mr. R. T. Crawford, Fellow in Astronomy, has assisted in checking the copy.

ON THE LAW OF TEMPERATURE IN GASEOUS BODIES,

By C. M. WOODWARD.

The demonstration of the formula, $T = \frac{K}{R}$, which Dr. T. J. J. SEE published in *A.J.* 455, ought not to pass without protest.

I cannot make my criticism clear without giving his assumptions and his line of proof.

1. He assumes that a gaseous globe, the equation of the gas being $\frac{P}{\sigma} = CT$, has a definite surface whose radius is R_0 and that at the surface the pressure is P_0 and the density σ_0. Now, there is no good reason to suppose that a pure gas, unrestrained save by the mutual attraction of its particles, has a definite limiting surface.

2. He assumes that the *pressure* at R_0 is directly measured by the weight of an element of mass: whereas it is the *variation* in the pressure which is measured by the weight. Thus the weight of an element of mass of the gas whose volume is $v_0 = dSdR$, is $\frac{kM_0 v_0 \sigma_0}{R_0^2}$, and this equals, not PdS as Dr. SEE assumes, but $dPdS$.

3. By considering the force of gravity as a sort of exterior solid piston pressing upon the gas, and then fancying that while the globe contracts the piston becomes both heavier and smaller, he arrives at the conclusion that the intensity of pressure is inversely as the 4th power of the radius, or $P = P_0 \left(\frac{R_0}{R}\right)^4$, the contraction being from R_0 to R. In point of fact this value of P, arrived at from two false premises, is utterly wrong. P is really inversely as R^2, or $P = \frac{A}{R^2}$, as is shown in my paper read before the St. Louis Academy of Science on March 20, 1899.

4. Dr. SEE gives correctly the ratio of the volumes before and after contraction as

$$\frac{v_0}{v} = \frac{\sigma}{\sigma_0} = \left(\frac{R_0}{R}\right)^3$$

This follows from geometry alone.

5. Dr. SEE now reasons as follows:

$$\text{Since} \qquad \frac{P}{\sigma} = CT$$

$$\text{and since} \qquad P = P_0 \frac{R_0^4}{R^4} \quad \text{and} \quad \sigma = \sigma_0 \frac{R_0^3}{R^3}$$

it follows by substitution, that

$$T = \frac{P_0 R_0^4 R^3}{C\sigma_0 R^4 R_0^3} = \frac{K}{R}$$

The conclusion is false for the reason that the value of P is false.

Dr. SEE appears to forget that when the volume of a given mass of gas is fixed by other considerations the pressure is independent of the force of gravity.

Dr. SEE leaves the problem of temperature still unsolved. Instead of finding the temperature from the pressure, the temperature is to be determined by the principle that the change of temperature during contraction must be such as to render the force of mutual attraction sufficient to do the work of compression.

For a solution of that problem, I beg leave to refer to my paper mentioned above.

Washington University, Saint Louis, Mo., 1899 March 29.

OBSERVATIONS OF COMET VII 1898,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

By E. F. CODDINGTON.

1899 Mt. Hamilton M.T.	★	No. Comp.	☄ — ★ $\Delta\alpha$	☄ — ★ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			s	′ ″	h m s	° ′ ″		
Feb. 6 7h 7m 18s	1	8 , 8	+ 4.42	+6 12.9	2 13 37.42	−37 25 20.5	9.471	0.897
8 6 57 1	3	8 , 8	+18.85	−0 28.2	16 13.49	36 22 48.5	9.452	0.898
11 7 8 30	5	8 , 8	−41.23	+4 24.1	20 6.99	34 50 35.2	9.503	0.885
13 7 9 9	7	8 , 8	−13.75	−5 56.4	22 41.93	33 50 48.5	9.514	0.880
15 7 11 49	9	8 , 8	+41.02	+2 14.6	2 25 15.31	−32 52 18.1	9.530	0.873

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	2 13 32.12	+0.88	−37 31 25.5	−7.9	DM. −37°872. Connected with *2
2	13 8.05	0.87	37 36 10.2	8.0	Gould's Zone-Catalogue. 2h330
3	15 53.77	0.87	36 22 12.9	7.4	9M.5. Connected with *4
4	13 2.77	0.85	36 27 6.8	7.6	Gould's General Catalogue 2338
5	20 47.36	0.86	31 51 52.0	7.3	10M. Connected with *6
6	20 18.96	0.86	35 1 33.1	7.3	Gould's Zone-Catalogue. 2h536
7	22 51.84	0.81	33 44 45.0	7.1	9M.5. Connected with *8
8	21 18.44	0.83	33 38 4 1	7.0	Gould's General Catalogue 2521
9	24 33.48	0.81	32 54 25.8	6.9	10M. Connected with *10
10	2 27 53.84	+0.82	−33 3 9.5	−7.1	Gould's General Catalogue 2657

The comet is still readily observable with the 12-inch telescope. The observation of Feb. 15, compared with the ephemeris, by C. J. Merfield (*A.J.* 454), gives the following residuals:

$$O-C, \quad \Delta\alpha = -0^s.7 \quad , \quad \Delta\delta = -3'\ 17''$$

Mt. Hamilton, 1899 *Feb.* 21.

COMETS OF THE YEAR 1898.

The dates are in Greenwich Mean Time, and the Elements only approximate.

Designation	Perihelion	☊	ω	*i*	*q*	φ	Discoverer	Date	Synonym	
		° ′	° ′	° ′		° ′		1898		
I	1898 Mar. 17.36	262 32	145 4	72 27	1.0985	. .	Perrine	Mar. 19	*b* 1898	
II	Mar. 20.39	100 52	173 21	17 0	0.9241	45 37	Perrine	Jan. 2	*a* 1898	Winnecke's
III	May 27.80	334 47	183 59	12 55	0.3407	57 49	Tebbutt	June 11	*d* 1898	Encke's
IV	July 4.60	206 27	172 52	25 12	1.6035	33 44	Hussey	June 16	*f* 1898	Wolf's
V	July 25.51	278 17	22 25	166 51	1.5013	. .	Giacobini	June 18	*g* 1898	
VI	Aug. 16.20	259 6	205 36	70 2	0.6265	. .	Perrine	June 14	*e* 1898	
VII	Sept. 14.05	73 59	233 16	69 56	1.7015	. .	Coddington	June 11	*c* 1898	
VIII	Sept. 20.15	95 51	4 38	22 30	2.2693	. .	Chase	Nov. 14	*j* 1898	
IX	Oct. 20.53	34 56	162 26	28 51	0.4195	. .	Perrine	Sept. 12	*h* 1898	
X	Nov. 23.16	96 20	123 34	140 21	0.7560	. .	Brooks	Oct. 20	*i* 1898	

NEW ASTEROIDS.

Communicated by Prof. Kreutz.

		1899	M.T.		α	δ	Daily Motion		Discoverer
	M		h m		h m s	° ′	s	′	
EG	11.3	Mar. 2	12 36.7	Heidelberg	11 37 48	+3 6	−36	+3	Wolf-Schwassman
EJ	10.8	3	10 31.2	"	15 20 20	+1 15	−60	+8	" "
EK	12.0	9	14 47.5	Vienna	12 28 47.5	+0 21.4	−36	+4	Palisa

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THE ORBIT OF ζ HERCULIS.

By ERIC DOOLITTLE.

Two discussions of this orbit have been recently published; one by Dr. SEE (*A.J.*, No. 357), and one by Dr. DOBERCK (*A.N.*, No. 3448). The residuals from the former orbit are small, except at the times of periastron passage, though they exhibit a somewhat systematic periodicity of sign. Dr. SEE states that it was found impossible to avoid this, owing doubtless to the absence of observations in the most critical part of the orbit.

The careful and elaborate investigation of Dr. DOBERCK was published two years later, and this included the observations of 1895 and 1896, which were of much value in fixing the position of periastron. The residuals in this orbit are very small, also, as may be seen by the table below, and the systematic occurrence of sign is almost entirely absent. Owing to the scarcity of observations near periastron, however, the residuals in this part of the orbit were in some cases exceedingly large; it was found necessary to reject an observation of DEMBOWSKI, based on four nights, and one of STRUVE on one night, as the residuals exceeded 30°. The recent observations by HUSSEY which are two years from periastron are also 16° in error, and all of these errors have the same sign.

The above orbits well represent the observations which are not too near periastron, and though at present their ephemerides differ by somewhat more than 30°, the predicted places will be practically the same by 1907. This difference seems to arise principally from the uncertainty of the time of periastron passage, the adjustment of which element is especially difficult and uncertain in this orbit.

The following investigation was begun about one year ago, upon the publication of Mr. HUSSEY's measures (*A.N.*, No. 3465). These are the only observations used which were not included in the lists published by Dr. SEE and Dr. DOBERCK. The first step was to group the annual means into twelve normal places, from which the six corrections to the elements were found in the usual manner. The two hundred and sixty-eight individual observations were then combined into twenty-nine normal places. The weights depending on the distance were then computed by the expression

$$\Delta\theta = \sqrt{\left[\left(\frac{\rho_o+\rho_c}{2a}\right)(\theta_o-\theta_c)\right]^2+\left[\frac{2(\rho_o-\rho_c)}{(\rho_o+\rho_c)}\cdot 57.3\right]^2}$$

where in many cases the second term was inappreciable, and a second series of weights were assigned equal to the square roots of the numbers of nights of observation in the respective normal places. By this means a single earlier observation has the same weight as a single observation made more recently, but the number of observations in later years is so greatly in excess that it seemed best not to further lower the weights of the earlier positions. Certain of OTTO STRUVE's and DEMBOWSKI's observations were, however, arbitrarily given larger weights, as was also the measure of HUSSEY. A single observation of MÄDLER in 1862 was rejected, its error being from fifty to seventy degrees.

The resulting elements are as follows: Dr. SEE's and Dr. DOBERCK's elements are also written for comparison:

	SEE	DOBERCK		New Elements	
	°	°	°		
Ω	37.5	54.06	±1.10	48.71	±0.71
λ	101.7	112.58	±1.12	110.39	±0.80
i	51.77	47.82	±1.16	45.03	±0.94
e	0.497	0.4566	±0.0046	0.4564	±0.0058
		°			
u	−10.2843	−10.1258	±0.0104	−10.1206	±0.0210
T	1864.80	1863.893	±0.159	1864.455	±0.067
P	35.00 yrs.	34.530	±0.035	34.547	
a	1″.4321	1″.355	±0″.0052	1″.381	±0″.007

It will be observed that the values of T differ sufficiently to cause great divergence in the values of θ near periastron. It may be that the small probable error obtained for this quantity shows that the value here assigned is near the truth, but where so many causes of systematic errors occur, but little can be inferred from the probable errors.

The orbits give widely different residuals only near periastron. The following table contains all of the observations within three years of the three successive periastron passages. The fourth column gives the residuals from the elements here published.

Date of Obs.	See	Doberck		Observer	θ
		Date of Periastron Passage, 1829.908.			
	°	°	°		
1826.63	− 3.7	− 1.2	− 1.1	8n Σ	23.4
*1828.73	+ 8.6	+32.5	+ 9.3	1n Σ	352.6
1832.75	+ 4.5	− 2.9	− 1.4	1n Σ	220.5
1834.45	+ 2.0	− 2.3	− 1.8	2n Σ	203.5
		Date of Periastron Passage, 1864.455.			
1862.54	−14.1	+12.1	+ 2.4	8n A	361.8
1862.71	−31.9	+ 4.8	−17.1	1n OΣ.	341.0
1862.91	+31.4	–	–	2n Ma.	410.9
*1863.49	− 9.2	+33.5	+11.6	4n A	343.0
1865.55	− 6.6	+ 2.8	− 6.3	3n Eng.	250.0
1866.74	+ 3.5	+ 2.8	− 1.0	5n A, 7n Da., 2n OΣ	232.5
		Date of Periastron Passage, 1899.002.			
1895.63	+ 2.3	+ 8.9	+ 4.0	See, Sch. Com. Le.	34.0
1896.58	−12.9	+ 9.3	− 2.0	Com.	14.3
1897.60	+28.9	+16.0	− 3.3	Hussey 3n	344.20

It will be observed that the largest residuals of Dr. Doberck's orbit occur in each case with that observation which is nearest periastron. He rejected those observations marked with an asterisk.

I have omitted Mädler's observation of 1892.61. An examination of the three observations made during this year can leave no doubt that Dembowski's is the most accurate, and this agrees well with the orbit. The increase of Dr. Doberck's residuals at this periastron is especially marked if we examine the excellent measures of Dembowski by themselves. They are the following:

	°		°
1858.56	− 2.3	1866.45	+11.1
1862.54	+12.1	1867.52	+ 5.1
1863.49	+33.5	1868.14	− 0.7

While the elements here published have not entirely destroyed these large residuals, it will be seen that they have considerably lessened them.

The following table gives the residuals computed with each of the three sets of elements for the dates of the annual means employed by Dr. See. To save space the values of the radius vector and its errors are omitted. It may be stated that these errors show little trace of systematic error, and, as may be inferred from the probable error of a given above, they are sufficiently small.

Date	See	Doberck	New Elements	Date	See	Doberck	New Elements	Date	See	Doberck	New Elements
	°	°	°	1854.46	+ 3.8	± 0.0	+ 0.1	1878.51	− 6.7	− 1.2	− 3.2
1782.55	−11.2	−19.1	−18.8	1855.46	+ 4.4	+ 0.8	+ 1.0	1879.54	− 4.1	+ 1.0	− 1.2
1826.63	− 3.7	− 1.2	− 4.9	1856.48	+ 2.6	+ 0.2	+ 0.3	1880.49	− 4.8	− 0.5	− 0.2
1828.71	+ 5.5	+25.6	+ 9.3	1857.61	+ 3.5	+ 0.5	+ 0.9	1881.49	− 3.3	+ 0.1	− 1.7
1832.72	+ 4.5	− 2.9	− 4.4	1858.58	+ 0.5	− 1.2	− 0.8	1882.60	− 1.6	+ 0.5	− 0.6
1834.45	+ 2.0	− 2.3	− 1.8	1859.58	− 1.0	− 0.4	+ 0.1	1883.60	+ 0.2	− 0.5	+ 0.3
1835.45	+ 5.3	+ 0.5	+ 1.2	1860.70	− 4.5	+ 1.2	− 1.5	1884.58	− 2.5	− 1.2	− 2.0
1836.60	+ 3.4	+ 0.2	+ 0.8	1861.50	− 9.9	+ 1.9	− 4.4	1885.58	− 0.7	− 0.8	− 1.4
1838.70	+ 1.0	+ 0.5	+ 0.7	1862.54	−14.1	+12.1	+ 2.4	1886.63	+ 2.0	+ 1.6	+ 0.8
1839.76	+ 2.0	+ 2.0	+ 2.4	1862.73	−31.9	+ 4.8	−17.1	1887.60	+ 1.3	+ 0.2	− 0.2
1840.66	+ 3.4	+ 5.0	+ 4.4	1863.49	− 9.2	+33.5	+11.6	1888.58	− 0.5	− 0.4	− 0.7
1841.56	− 0.8	+ 1.4	− 0.1	1865.55	− 6.6	+ 4.8	− 6.3	1889.56	+ 2.1	+ 0.5	+ 0.7
1842.54	+ 1.7	+ 4.2	+ 2.8	1866.74	+ 3.5	+ 2.8	− 1.0	1890.60	+ 0.2	± 0.0	+ 0.1
1843.65	− 2.0	− 0.5	− 1.7	1867.62	+ 6.3	+ 3.8	+ 2.1	1891.57	+ 1.3	+ 0.7	+ 0.7
1844.50	− 2.4	− 0.4	− 1.4	1868.54	+ 0.6	− 1.1	− 2.4	1892.60	− 0.2	− 0.2	− 0.1
1845.64	+ 2.0	+ 4.9	+ 1.8	1869.60	+ 3.6	+ 3.0	+ 1.6	1893.74	− 0.6	+ 0.6	+ 0.2
1846.79	− 0.8	− 0.5	− 1.6	1870.54	+ 1.1	+ 0.6	+ 0.6	1894.58	− 2.0	+ 3.1	+ 1.7
1847.55	+ 0.5	+ 0.1	− 0.8	1871.52	− 1.6	− 1.3	− 0.8	1895.32	− 2.1	+ 4.5	+ 4.0
1848.59	+ 0.4	− 0.4	− 1.4	1872.55	− 2.7	− 0.7	− 0.7	1895.63	+ 2.3	+ 8.9	+ 4.0
1849.48	+ 2.7	+ 1.3	+ 0.4	1873.60	− 2.2	+ 1.0	+ 0.6	1896.58	−12.9	+ 9.3	− 2.0
1850.36	+ 1.6	− 0.3	− 1.1	1874.60	− 1.1	+ 3.0	+ 2.3	†1897.60	+28.9	+16.0	− 3.3
1851.50	+ 2.2	− 0.5	− 1.0	1875.56	− 6.0	− 0.4	− 2.0				
1852.67	+ 4.0	+ 0.5	+ 0.9	1876.56	− 7.6	− 0.6	− 2.3				
1853.46	+ 2.2	− 1.3	− 1.2	1877.57	− 3.8	+ 1.6	± 0.0				

† I regret that my own measures attributed to this system (*A.J.*, No. 416), undoubtedly belong to the preceding star on my observing list, namely, Σ 1964 B.C.

The following is a short ephemeris. A few observations, if they can be secured during this year, will show at once which of the three orbits is to be preferred.

The Flower Observatory, 1899 *March* 5.

	θ	ρ		θ	ρ
	°	°		°	°
1899.50	273.9	0.59	1902.50	215.9	1.04
1900.50	247.7	0.77	1903.50	206.7	1.14
1901.50	230.6	0.92			

OBSERVATIONS OF MINOR PLANETS,

MADE WITH THE 12 AND 36-INCH REFRACTORS OF THE LICK OBSERVATORY.

By E. F. CODDINGTON.

1898 Mt. Hamilton M.T.	⁎	No. Comp.	Planet − ⁎ $\Delta\alpha$	Planet − ⁎ $\Delta\delta$	Planet's apparent α	Planet's apparent δ	$\log p\Delta$ for α	$\log p\Delta$ for δ
			(334) Chicago.					
	h m s		m s	′ ″	h m s	° ′ ″		
May 19	14 39 1	1	8, 8	−0 13.45	+1 49.6	16 41 52.47	−16 30 7.5	9.350	0.845
June 2	12 1 39	3	10, 10	+0 16.04	−3 2.9	16 32 36.62	−16 13 55.8	8.538	0.848
9	12 52 20	5	8, 8	−0 3.70	−3 58.6	16 27 56.89	−16 7 34.1	9.310	0.837
10	11 48 22	7	10, 10	−0 23.40	−0 21.2	16 27 19.86	−16 6 51.6	8.923	0.846
23	11 9 20	8	8, 8	+0 8.29	−3 0.8	16 19 39.74	−16 0 31.1	9.096	0.842
			(25) Phocaea.					
Aug. 14	11 48 7	9	10, 10	+0 29.03	−5 49.3	20 43 46.27	+26 46 53.8	8.945	0.212
15	8 20 22	10	10, 6	−2 0.86	+5 54.5	20 43 19.21	+26 37 43.3	n9.536	0.377
16	12 13 26	11	12, 8	−1 24.43	−2 19.6	20 42 42.31	+26 24 35.1	9.217	0.255
			(169) Zelia.					
Sept. 16	13 35 43	12	8, 8	−0 7.35	+6 16.3	3 45 15.53	+24 57 47.6	n9.481	0.382
17	13 34 37	13	10, 10	−0 21.18	+0 28.6	3 45 36.78	+25 2 44.9	n9.475	0.377
18	13 4 42	13	10, 10	−0 2.45	+5 18.4	3 45 55.53	+25 7 34.7	n9.538	0.412
20	11 1 47	14	10, 10	−0 12.68	−3 46.0	3 46 26.89	+25 16 40.5	n9.689	0.582
			(105) Artemis.					
Nov. 9	16 0 53	15	8, 8	−0 15.24	+6 39.5	5 16 16.06	− 4 14 30.2	9.379	0.759
			(139) Juewa.					
Dec. 10	11 57 1	17	8, 8	−0 4.83	+3 57.8	6 9 0.79	+40 38 10.3	n9.139	n9.622
11	9 45 35	19	8, 8	+0 27.99	−1 28.8	6 7 59.98	+40 40 30.6	n9.636	9.890
12	10 1 19	21	8, 8	+0 47.04	−4 57.5	6 6 51.07	+40 42 59.4	n9.592	9.693

Mean Places for 1898.0 of Comparison-Stars.

⁎	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 42 2.22	+3.70	−16 31 46.7	−10.4	Connected with ⁎2
2	16 43 30.30	+3.70	−16 35 34.8	−10.3	DM. −16°4353, Skinner, 2 Wash.Obs., A.G.Catal.
3	16 32 16.71	+3.87	−16 10 42.1	−10.8	Connected with ⁎4
4	16 35 58.61	+3.87	−16 9 59.8	−10.5	DM. −16°4328, Skinner, 3 Wash.Obs., A.G.Catal.
5	16 27 56.63	+3.96	−16 3 24.4	−11.1	Connected with ⁎6
6	16 29 31.56	+3.96	−16 3 17.2	−11.0	DM. −15°4346, Skinner, 2 Wash.Obs., A.G.Catal.
7	16 27 39.30	+3.96	−16 6 19.3	−11.1	Connected with ⁎5
8	16 19 27.46	+3.99	−15 57 18.9	−11.4	DM. −15°4320, Skinner, 2 Wash.Obs., A.G.Catal.
9	20 43 13.37	+3.87	+26 52 25.2	+17.9	Graham, Camb. A.G. Catal. 11749
10	20 45 16.19	+3.88	+26 31 30.6	+18.2	" " " " 11806
11	20 44 2.87	+3.87	+26 26 36.4	+18.3	" " " " 11774
12	3 45 18.55	+4.33	+24 51 16.9	+14.4	½ [Camb.A.G.Catal.'77 + Berl. B.A.G.Catal.1225]
13	3 45 53.60	+4.36	+25 2 1.9	+14.4	½ [Camb.A.G.Catal.'85 + Berl. B.A.G.Catal.1230]
14	3 46 35.12	+4.45	+25 20 12.1	+14.4	Graham, Camb. A.G. Catal. 1892
15	5 16 26.68	+4.62	− 4 21 22.1	+12.4	10ᴹ. Connected with ⁎16
16	5 14 27.83	+4.63	− 4 26 49.4	+12.6	Paris Catal. 6134
17	6 8 58.53	+7.09	+40 34 14.0	− 1.5	DM. +40°1531 9ᴹ.3. Connected with ⁎18
18	6 11 44.43	+7.09	+40 33 36.8	− 2.0	Deichmüller, Bonn A.G. Catal. 5157
19	6 7 24.86	+7.13	+40 42 0.6	− 1.2	DM. +40°1526 9ᴹ.4. Connected with ⁎20
20	6 5 47.67	+7.13	+40 38 33.6	− 1.0	Deichmüller, Bonn A.G. Catal. 5083
21	6 5 56.84	+7.19	+40 47 57.8	− 0.9	Deichmüller, Bonn A.G. Catal. 5086.

The observations of (334), *Chicago*, were made with the 36-inch refractor, all others with the 12-inch.

All of them, except (25), *Phocaea*, were located by means of the Crocker photographic telescope. (169), *Zelia*, was found upon a plate exposed for the *Pleiades*, and a few observations were made for the purpose of identification.

Mt. Hamilton, 1899 *March* 17.

ON THE TEMPERATURE OF GASEOUS CELESTIAL BODIES,

By A. S. CHESSIN.

Professor NEWCOMB's note in *A.J.* 458 and my reply to the same (*ibid*) are apt to cause a misunderstanding which I will endeavor to clear in the present note. A correspondence with Professor NEWCOMB subsequent to the publication of the two notes in *A.J.*, No. 458, brought to light the fact that we were considering two different problems.

Professor NEWCOMB states the following theoretical problem of aerostatics.

Let a globe of perfect gas be in a state of equilibrium at the absolute temperature T_0, function of the distance from the center of the globe. As long as there is no radiation or absorption of heat this equilibrium will be preserved. Suppose now that by radiation the gaseous mass contracts from a globe of radius R_0 to one of radius R, after which the radiation of heat is stopped and the gaseous mass is allowed to return to a state of equilibrium. What will now be the absolute temperature T assuming that the law of MARIOTTE-GAY-LUSSAC *is absolutely correct?*

If, moreover, we assume a *uniform* contraction throughout the body, the answer will be that which Professor NEWCOMB rightly expected, namely (*)

$$T = \frac{R_0 T_0}{R} \tag{1}$$

How far the problem as here stated differs from practical problems of aerostatics may be seen from the following: The density of a gaseous globe in equilibrium between the gravitational forces and the elasticity due to temperature will necessarily be greater at the center than on the surface; therefore the contraction of the mass will *not* be uniform; a further complication as to the new state of equilibrium arises from the fact that the radiation of heat will depend both on the law of density and on the distance from the center, so that the result of the radiation will be a new law of density and a new law of temperature. If it is $T_0 = f(r_0)$ in the first state of equilibrium it will be $T = q(r)$ in the new state, the new function q generally differing from f.

But when we come to actual problems of celestial bodies the deviations from the conditions as stated above become enormous. There is certainly no reason to believe that celestial bodies radiate and contract by fits and starts, waiting from time to time long enough to return to a state of equilibrium. If, therefore, the problem as stated by Professor NEWCOMB is to be applied to celestial bodies, this must be done with the distinct understanding that the results obtained are based on several hypotheses, and that they are, at the best, only an approximation of what may be taking place in reality. A. RITTER, in his interesting researches on the constitution of gaseous celestial bodies (*Wied. Ann.*, Vols. V–XX) among other problems solved the one stated above. But he was fully alive to the difficulty of applying his results to celestial bodies. He says, on p. 558 of Vol. V, *Wied. Ann.* (1878): "*Die Entscheidung der Frage wie weit diese Hypothese* sich in Einklang bringen lassen wird mit den Gesetzen der Wärmeleitung und Wärmestrahlung und wie weit es überhaupt zulässig sein wird die aus dieser Hypothese gezogenen Schlussfolgerungen auf die wirklich existirenden Weltkörper anzuwenden, wird man künftigen weiteren Forschungen überlassen müssen. Zweck der vorstehenden Untersuchung war: die Consequenzen jener anscheinend fruchtbaren Hypothese bis zu derjenigen grenze zu verfolgen, wo Widersprüche mit der Erfahrung oder mit anderweit als richtig erkannten Naturgesetzen eine Modification derselben gebieten.*"

The fact that a contraction of the sun's mass would suffice to account for the source of heat in that body was announced in a public lecture by HELMHOLTZ as far back as 1854. That contraction of a gaseous celestial body could generate more heat than is lost through radiation was also known for some twenty-five years, LANE's law being an expression of this very probable hypothesis. But from all this to a "fundamental law of nature" there is a wide chasm which it seems impossible to cross in the present state of our knowledge. The problem which Dr. SEE has proposed to solve, and which I had in view when I replied to Professor NEWCOMB, is really the following one:

A radiating gaseous mass contracts under the action of gravitational forces. What is the temperature-distribution in the mass at any given moment?

This is a problem of aerodynamics, and not of aerostatics. I am happy to say, therefore, that there is no disagreement between the statements of Professor NEWCOMB and myself as far as the matter discussed in the two notes of *A.J.* 458 is concerned.

The question whether the solution of the statical problem proposed by Professor NEWCOMB could be substituted, even as an approximation, for the solution of the other dynamical problem, which Dr. SEE has vainly tried to solve, remains in the domain of speculation. At any rate, a presumption to formulate an *accurate law* on a basis consisting of hypotheses, must be logically condemned. Formula (1)

*See *Wiedeman's Annalen*, 1878: A. RITTER, *Untersuchungen über die Höhe der Atmosphäre und die Constitution gasförmigen Weltkörper; Zweite Abtheilung.*

* *i.e.* hypothesis of a state of equilibrium. In this portion of his work RITTER considers what he calls the "indifferent" state of equilibrium of a gaseous mass. This term is equivalent with that of "convective" equilibrium used by English writers. Formula (1), however, is independent of the "character" of the equilibrium, provided T be a function of the distance from the center.

can only be taken for what it is worth, and that is pointed out in RITTER's own words above quoted. It is doubtful whether anybody except Dr. SEE himself will class RITTER's formula (*alias* SEE's "remarkable" law) among the "fundamental laws of nature" like the law of gravitation.

While I have already pointed out that the derivation of formula (1) by Dr. SEE is erroneous, I may add that what he gives as his result in *A.J.* 455, namely, the formula

$$(2) \qquad T = \frac{\text{Constant}}{R}$$

is entirely wrong. In fact, in (1) we have

$$T = \varphi(r) \quad ; \quad T_0 = f(r_0)$$

r and r_0 being the radii of the *same* sphere after and before the contraction of the globe, and therefore $T_0 R_0$ *is not a constant* for the body. When we come to analyze Dr. SEE's derivation of his law we are really puzzled by the meaning of his formula (2) as much as by the logic of his reasoning. If his letter R denotes distance from center for any of the concentric layers of which the globe may be composed, then $T_0 R_0$ is not constant; if, which seems to be more probable, R denotes the radius of the entire globe, then where does he get his pressure on the surface of the globe?

Not less startling are Dr. SEE's "far-reaching" conclusions. I will pick out one at random:

The earth received more heat in geological times than at present. This conclusion is based on the assumption that the total radiation of the sun is proportional to its surface and to its temperature. Both assumptions are wrong, even if we accept Dr. SEE's law. First, the radiation probably increases from the surface towards the center of the sun, reaches a maximum, after which it again decreases as it reaches the center. Second, the radiation is proportional to a higher than the first degree of temperature, probably near to the fourth degree. The greater heat of the earth in geological times is far better explained by geological reasons.

The true meaning of Dr. SEE's statement that his conclusions are "far-reaching" lies undoubtedly in the enormous distance of the stars from our own globe.

OBSERVATIONS OF MINOR PLANETS,

MADE AT VASSAR COLLEGE OBSERVATORY WITH THE 12-INCH REFRACTOR,

By MARY W. WHITNEY AND CAROLINE E. FURNESS.

1898 Greenwich M.T.	*	No. Comp.	Planet — * $\Delta\alpha$	Planet — * $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
			(354) *Eleanora.*						
Feb. 24 14ʰ 31ᵐ 39ˢ	1	7	+1ᵐ 47ˢ.05	−5′ 25″.0	11ʰ 9ᵐ 6ˢ.22	+16° 33′ 59″.9	*n*9.536	0.639	W
26 14 55 42	2	7	−1 39.87	+7 31.9	11 7 42.02	+17 0 50.2	*n*9.471	0.614	W
28 14 33 48	3	10	−1 27.71	+7 15.3	11 6 17.10	+17 26 58.0	*n*9.500	0.616	W
			(347) *Pariana.*						
Mar. 17 14 15 51	4	9	+1 15.93	−1 23.8	11 51 20.91	+23 43 42.6	*n*9.516	0.532	F
			(151) *Abundantia.*						
Mar. 17 16 10 55	5	11	+0 16.90	+3 5.7	12 17 22.39	+ 5 28 2.3	*n*9.176	0.719	W
25 14 2 21	6	8	−1 16.65	+0 26.3	12 10 1.06	+ 5 56 40.1	*n*9.475	0.726	W
			(363) *S.*						
Mar. 17 18 50 25	7	9	−0 36.38	−0 7.2	13 37 49.11	− 3 1 2.8	6.955	0.792	W
25 15 47 51	8	7	+1 22.45	−4 30.4	13 32 27.97	− 2 29 54.2	*n*9.419	0.784	W
			(82) *Alkmene.*						
Apr. 8 14 23 32	9	9	−0 35.22	+2 1.0	13 32 45.76	− 9 20 19.7	*n*9.491	0.816	F
			(56) *Melete.*						
Apr. 8 14 43 3	10	7	−1 5.43	−8 47.8	12 25 24.98	− 3 18 2.8	*n*9.221	0.792	F
			Eros.						
Nov. 7 11 16 19	11	8	−1 4.33	−1 32.3	. . . .	. . . .	. .	. .	W
11 12 22 50	12	8	−0 31.54	+1 13.9	21 12 39.08	− 4 4 57.0	9.269	0.797	W
12 12 4 19	12	10	+0 58.86	+7 7.5	21 14 9.65	− 3 59 3.5	9.196	0.797	W
15 12 4 45	13	9	−0 43.35	+9 6.2	21 18 52.84	− 3 40 40.8	9.231	0.795	W

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	11 7 16.27	+2.90	+16 39 41.6	−16.7	Bonn VI, +16°2229
2	11 9 18.98	+2.91	+16 53 35.1	−16.8	A.G. Berlin A 4391
3	11 7 41.86	+2.95	+17 19 39.4	−16.7	A.G. Berlin A 4384
4	11 53 1.85	+3.13	+23 45 24.5	−18.1	A.G. Berlin B 4407
5	12 17 2.59	+2.90	+ 5 25 15.8	−19.2	½ (Paris 15130 + Glasgow 1870, 3153)
6	12 11 14.77	+2.94	+ 5 56 32.8	−19.0	A.G. Leipzig II, 6063
7	13 38 22.74	+2.75	− 3 0 36.5	−19.1	Paris 16767
8	13 31 2.66	+2.86	− 2 25 4.3	−19.5	Paris 16623
9	13 33 17.95	+3.03	− 9 22 1.2	−19.5	½[Radc. 1890, 3535 + ⅓ (Mu. I + 2 Mu. II, 4953)]
10	12 26 27.45	+2.96	− 3 8 55.3	−19.7	⅓ (Munich I + 2 Munich II, 4176)
11	21 7 54	. .	− 4 25.0	. .	S.DM. −4°5393, ($8^M.7$)
12	21 13 7.04	{ +3.58 / 3.57 }	− 4 6 31.0	+20.1	Karlsruhe, Vol. V.
13	21 19 32.60	+3.56	− 3 50 7.5	+20.6	½ (Radcliffe 1890 + Glasgow 1870), (20 *Aquarii*)

MICROMETRIC MEASURES OF THE SATELLITE OF *NEPTUNE*,

By D. A. DREW.

These measures of the satellite of *Neptune* were made by Mr. Cogshall and myself with the 24-inch refractor and Clark micrometer of the Lowell Observatory.

For all the measures there was a plan adopted, which, from our own and others' experience, seemed to promise the best results.

According to this plan a power of about 500 was to be used, and the wires were to be always, although sometimes faintly, illuminated with a ruby light. The eyes were to be kept either parallel or perpendicular to the wires. In taking angles, the wires were to be brought into coincidence and made to bisect both disks. The micrometer was then to be turned through 90° and the distance measured by double distances, the wires bisecting both disks. The measures were to be taken in the following order and of the number given: four angles, then four double distances, and finally four angles. As the satellite is always rather faint, especially when near an illuminated wire, I was to take the measure while Mr. Cogshall was to read the micrometer and note the time. In this way my eyes were to be saved the constant readjustment of the pupils.

This plan was strictly followed with the exception of the number of measures made.

On December 7 a rather bright star was found in the field with *Neptune*. The planet's position with respect to this star is given as the last of the measures. This star was identified as DM. +21°913.

In the various columns will be found the date of observation, the Greenwich M.T., t, the true position-angle p, the distance s, and the number of measures n.

Date	t	p	s	n	Remarks	Date	t	p	s	n	Remarks
1898	h m s	°	″			1898	h m s	°	″		
	22 44 15	307.40	. .	4	Moonlight, hazy	Sept. 27	22 31 30	. .	11.51	4	Seeing fair
Sept. 9	22 52 52	. .	11.86	4	Seeing fair		22 42 45	281.18	. .	4	Moonlight
	23 1 30	305.08	. .	4			21 58 15	176.40	. .	4	Satellite very faint
	22 31 30	122.67	. .	4		Sept. 29	22 11 38	. .	10.37	4	Seeing poor
Sept. 12	22 40 52	. .	12.53	4	Seeing good		22 22 30	175.95	. .	4	Moonlight
	22 55 12	119.48	. .	5			21 57 15	142.43	. .	4	
	22 9 30	24.47	. .	4		Oct. 17	22 8 15	. .	11.32	4	Seeing good
Sept. 14	22 21 45	. .	12.29	4	Seeing fair		22 18 0	142.07	. .	4	[easy
	22 32 45	23.20	. .	4			21 53 30	262.70	. .	4	Satellite bright and
	22 9 30	113.55	. .	4		Oct. 21	22 6 30	. .	16.57	4	Seeing good
Sept. 18	22 23 45	. .	13.37	4	Seeing good		22 15 45	261.47	. .	4	
	22 37 30	112.47	. .	4			22 53 30	189.52	. .	4	
	22 23 0	69.27	. .	4	Satellite very faint	Nov. 9	23 5 7	. .	10.54	4	Seeing fair
Sept. 19	22 34 45	. .	16.42	4	Seeing poor		23 13 45	186.43	. .	4	
	22 49 45	68.15	. .	4			20 9 45	264.10	. .	4	
	21 50 45	246.98	. .	4	Satellite very faint	Dec. 7	20 24 6	. .	16.84	5	Seeing good
Sept. 22	21 58 45	. .	16.34	4	Seeing poor		20 37 30	263.07	. .	4	
	22 8 30	246.90	. .	4			20 42 0	297.75	. .	4	Seeing good
	22 18 45	282.55	. .	4	Satellite faint		20 48 30	. .	1′ 15.12	6	

Baraboo, Wis., 1899 *March* 28.

EPHEMERIS OF *EROS*,

BY HENRY NORRIS RUSSELL.

For Greenwich Midnight. Continued from *A.J.* 457.

1899	α	δ	log Δ	Mag.	1899	α	δ	log Δ	Mag.
	h m s	° ′ ″				h m s	° ′ ″		
April 24.5	4 57 2.27	+24 14 14.6			May 16.5	6 25 25.10	+22 23 52.6	0.2320	
26.5	5 5 4.82	24 11 47.9	0.2262	12.3	18.5	6 33 20.90	22 4 57.7		
28.5	5 13 8.06	24 7 19.9			20.5	6 41 14.61	21 44 39.4	0.2336	12.4
30.5	5 21 11.70	24 2 20.3	0.2272		22.5	6 49 6.02	21 22 59.7		
May 2.5	5 29 15.51	23 55 18.9			24.5	6 56 54.97	21 0 0.6	0.2354	
4.5	5 37 19.25	23 46 45.8	0.2281	12.3	26.5	7 4 41.28	20 35 44.1		
6.5	5 45 22.65	23 36 41.3			28.5	7 12 24.83	20 10 13.4	0.2374	12.4
8.5	5 53 25.43	23 25 5.8	0.2293		30.5	7 20 5.51	19 43 29.8		
10.5	6 1 27.33	23 12 0.1			June 1.5	7 27 43.24	19 15 36.0	0.2395	
12.5	6 9 28.08	22 57 25.3	0.2306	12.4	3.5	7 35 17.97	18 46 34.3		
14.5	6 17 27.41	+22 41 22.3			5.5	7 42 49.66	+18 16 27.0	0.2419	12.5

OBSERVATIONS OF *EROS*,

MADE WITH THE 26-INCH EQUATORIAL OF THE LEANDER McCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA,

BY ORMOND STONE, H. R. MORGAN, AND E. O. EASTWOOD.

1898 Eastern M.T.		*	No. Comp.	Planet — *		Planet's Apparent		log pΔ		Obs.
				Δα	Δδ	α	δ	for α	for δ	
	h m s			m s	′ ″	h m s	° ′ ″			
Sept. 23	9 59 16	1	20 , 2	+0 17.26	+0 44.0	20 36 21.03	−6 20 36.7	9.2104	0.7862	S
	11 12 53	1	18 , 6	+0 16.26	+0 44.7	20 36 20.03	−6 20 36.0	9.4671	0.7774	M
24	9 19 24	1	32 , 8	+0 2.35	+1 4.7	20 36 6.12	−6 20 16.0	8.9601	0.7884	M
25	8 14 43	1	16 , 4	−0 9.40	+1 29.1	20 35 54.36	−6 19 51.6	9.3123	0.7858	S
26	9 25 15	1	30 , 8	−0 19.13	+2 6.6	20 35 44.61	−6 19 14.2	9.0770	0.7876	M
27	9 31 3	1	28 , 8	−0 25.46	+2 36.2	20 35 38.27	−6 18 44.6	9.1426	0.7869	M
28	8 44 24	1	35 , 4	−0 28.48	+3 13.0	20 35 35.23	−6 18 7.8	8.7242	0.7889	S
	11 8 47	1	20 , 8	−0 29.01	+3 17.7	20 35 34.70	−6 18 3.1	9.4996	0.7747	E
	11 49 15	1	28 , 8	−0 28.98	+3 19.0	20 35 34.73	−6 18 1.8	9.5717	0.7674	M
29	9 18 48	1	16 , 4	−0 28.86	+3 57.2	20 35 34.83	−6 17 23.6	9.1121	0.7871	S
	10 22 11	1	32 , 4	−0 28.93	+4 0.3	20 35 34.76	−6 17 20.5	9.3947	0.7809	M
30	11 50 38	1	32 , 8	−0 25.99	+4 51.3	20 35 37.68	−6 16 29.6	9.5859	0.7654	E
Oct. 12	10 40 24	2	24 , 8	+1 8.45	−2 32.7	20 39 45.19	−5 59 42.5	9.5440	0.7691	E
13	8 3 51	2	24 , 4	+1 41.89	−0 43.7	20 40 18.60	−5 57 53.5	8.9091	0.7885	S
22	9 29 24	3	12 , 4	−0 24.56	−1 33.5	20 47 36.50	−5 33 57.2	9.4614	0.7730	M
	10 11 56	3	24 , 6	−0 22.93	−1 28.9	20 47 38.13	−5 33 52.6	9.5477	0.7665	M
	10 48 24	3	32 , 8	−0 21.34	−1 24.2	20 47 39.72	−5 33 47.9	9.5990	0.7599	E
24	8 58 4	3	4	. . . .	+4 59.6	. . . .	−5 27 24.2	9.3999	0.7759	M
28	7 50 37	4	28 , 4	−1 21.12	−2 23.0	20 53 54.13	−5 9 30.6	9.1602	0.7780	S
	9 53 37	4	24 , 8	−1 15.28	−1 16.4	20 53 59.97	−5 8 24.0	9.5450	0.7645	E
	10 43 16	4	12 , 8	−1 13.11	−1 8.8	20 54 2.14	−5 8 16.4	9.6117	0.7560	M
31	10 21 46	5	20 , 4	+1 3.22	+3 42.9	20 57 37.26	−4 59 55.6	9.5922	0.7578	M
Nov. 3	7 18 38	6	35 , 4	+1 3.23	−1 14.7	21 1 17.82	−4 47 0.9	9.0609	0.7758	S
	7 53 40	7	40 , 4	−1 5.69	+4 37.7	21 1 19.91	−4 46 49.9	9.2616	0.7737	S
	8 44 14	7	25 , 4	−1 2.88	+4 48.0	21 1 22.72	−4 46 39.6	9.4329	0.7692	S
	8 44 14	8	25 , 4	−2 5.98	+3 17.9	21 1 22.66	−4 46 45.5	9.4329	0.7692	S
	9 52 9	6	30 , 4	+1 11.47	−0 44.4	21 1 26.06	−4 46 30.6	9.5705	0.7602	M
	9 52 9	7	30 , 4	−0 59.34	+5 1.7	21 1 26.26	−4 46 25.9	9.5705	0.7601	M
	9 52 9	8	30 , 4	−2 2.41	+3 31.9	21 1 26.23	−4 46 31.5	9.5705	0.7601	M
7	7 19 5	9	30 , 4	−1 10.86	−2 4.2	21 6 46.61	−4 27 7.7	9.1284	0.7726	S
	8 24 47	9	40 , 8	−1 7.17	−1 49.1	21 6 50.30	−4 26 52.6	9.4084	0.7678	E
	9 19 25	9	24 , 8	−1 3.92	−1 37.1	21 6 53.55	−4 26 40.6	9.5294	0.7618	E.
14	7 52 18	10	30 , 4	−1 22.75	+0 57.0	21 17 20.02	−3 46 48.5	9.3614	0.7644	S
	7 52 18	11	30 , 4	−2 16.22	+3 0.1	21 17 20.06	−3 46 46.5	9.3614	0.7644	S
	9 9 52	11	22 , 4	−2 11.44	+3 22.0	21 17 24.84	−3 46 24.6	9.5466	0.7569	E
	9 9 52	10	22 , 4	−1 17.94	+1 18.7	21 17 24.83	−3 46 26.8	9.5466	0.7569	E
	9 57 26	11	12 , 4	−2 8.15	+3 33.4	21 17 28.13	−3 46 13.2	9.6087	0.7509	E
	9 57 26	10	22 , 4	−1 14.68	+1 30.6	21 17 28.09	−3 46 14.9	9.6087	0.7509	E

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 35 59.61	+1.16	−6 21 38.4	+17.7	Radcliffe 5568
. .	. . . .	+1.16	. . . . .	+17.7	
. .	. . . .	+1.15	. . . . .	+17.7	
. .	. . . .	+1.13	. . . . .	+17.6	
. .	. . . .	+1.12	. . . . .	+17.6	
. .	. . . .	+1.10	. . . . .	+17.6	
. .	. . . .	+1.08	. . . . .	+17.6	
. .	. . . .	+1.06	. . . . .	+17.5	
2	20 38 32.81	+3.90	−5 57 27.5	+17.7	Vienna III, Karlsruhe
. .	. . . .	+3.87	. . . . .	+17.7	
3	20 47 57.26	+3.80	−5 32 42.3	+18.6	Munich II, 10935
. .	. . . .	+3.77	. . . . .	+18.5	
4	20 55 11.51	+3.71	−5 7 26.6	+19.0	Radcliffe 5655
5	20 56 30.36	+3.68	−5 3 57.6	+19.1	W
6	21 0 10.93	+3.66	−4 46 5.6	+19.4	Radcliffe 5674
7	21 2 21.93	+3.67	−4 51 47.1	+19.5	Munich I, 27291
8	21 3 24.96	+3.68	−4 50 23.2	+19.8	Munich I, 27352 ; Munich II, 11258
9	21 7 53.83	+3.64	−4 25 23.4	+19.9	W
10	21 18 39.20	+3.57	−3 18 6.1	+20.6	W
11	21 19 32.71	+3.57	−3 50 7.2	+20.6	Radcliffe 5776

Places of stars marked "W" were determined at the Washington Observatory by special request.

OBSERVATION OF COMET 1898 VII,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

BY E. F. CODDINGTON.

Mt. Hamilton M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
1899 h m s			m s	′ ″	h m s	° ′ ″		
Feb. 26 7 21 39	1	8 , 8	+0 15.05	−4 42.0	2 39 1.84	−27 50 52.3	9.592	0.841

Mean Places for 1899.0 of Comparison-Star.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	2 38 46.05	+0.74	−27 46 4.6	−5.7	11ᴹ. Connected with *2
2	2 37 11.16	+0.74	−27 47 32.4	−5.6	Gould's Zone Catalogue, 2^h1008

Comparing the above observation with places computed from my elements (*A.J.* 441), I get the following residuals:

$$O-C, \quad \Delta\alpha = +8^s.09 \quad , \quad \Delta\delta = +5' \, 35''.9$$

These elements were computed from observations of June 11, 18 and 26, 1898. From the last of these dates to that of the observation above, the comet described a heliocentric arc of 119°.

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THE LIMITS OF TEMPORARY STABILITY OF SATELLITE MOTION, WITH AN APPLICATION TO THE QUESTION OF THE EXISTENCE OF AN UNSEEN BODY IN THE BINARY SYSTEM F.70 *OPHIUCHI*.

By F. R. MOULTON.

The verifications of the predictions that the unexplained irregularities in the orbit of *Uranus* were due to the action of an unknown planet, and that *Sirius* and *Procyon* were attended by unseen companions, naturally lead astronomers to assume as the cause of anomalous motions the existence of neighboring bodies not yet observed. Such hypotheses have *à priori* more probability since the phenomena of certain classes of variable stars have proven that there are great numbers of dark bodies in the heavens as well as bright ones. Besides, peculiarities in the motions of a few double stars have been observed, and as astronomers accumulate more and more material, doubtless many such cases will be found.

But when it seems necessary to assume the existence of a dark star in a binary system, the question of the stability of the motion required to satisfy the observations should always be investigated. Such considerations will in many cases prove to be effective checks upon the assumptions.

Unfortunately the questions of stability are the most difficult with which astronomers have attempted to deal, and there are as yet no perfectly rigorous results except in the case of periodic orbits, which have not been found in nature. Therefore, in this paper the problem will be considered in a very restricted form, but the results will have the merit of being easily applied.

1. The Limits of Temporary Stability of Satellite Motion.

Suppose there are two known bodies which, for convenience, will be called the star and the planet. Suppose that the observations of the motion of the planet seem to demand the assumption of the existence of a satellite revolving around it. It is proposed to find a distance from the planet, beyond which the satellite cannot make more than a limited number of revolutions in curves approximately elliptical in form, without passing away from the planet to the star. If this limit is reached the motion will be considered to be not temporarily stable: if it is nearly reached the question will be in doubt, and further investigation will be necessary to make the assumption safe.

Since the limit for certain instability is what is sought several simplifications may be introduced in such a way that the region of temporary stability will be enlarged: that is, every time the problem is modified it will be done so that the perturbations of the motion of the satellite caused by the star will be less instead of greater. As the inclination of the plane of the orbit of the satellite to the plane of the orbit of the planet is in general unknown, we shall assume for the sake of definiteness that it is zero. The simplifications introduced by this assumption are not important and any other might be used almost equally well. If the satellite motion is stable, the center of gravity of the planet and satellite will describe very nearly an ellipse. We shall assume that it is strictly an ellipse, and further that the eccentricity is zero. Finally, it will be supposed that the satellite is an infinitesimal particle revolving around such a mass at the center of gravity that its motion, undisturbed by the star, would be exactly the same as the actual undisturbed motion when both the planet and satellite are supposed to be finite.

It is easily seen that modified systems have been successively taken where the perturbations arising from the action of the star are less and less; and it will be inferred that in those cases where the last system is not temporarily stable, the original one lacks stability also. While such a process is efficient in revealing instability, it could not be used to establish stability.

The problem is thus reduced to one where two of the bodies are finite, describing circles around their common center of gravity, and the third is infinitesimal moving in the same plane. If we denote by M and m the masses of the star and planet respectively, the differential equations

of motion of the infinitesimal body referred to fixed rectangular axes, with the origin at the center of gravity of the system, are

$$(1)\qquad \begin{cases} \dfrac{d^2\xi}{dt^2} = \dfrac{\partial U}{\partial \xi} \\[2ex] \dfrac{d^2\eta}{dt^2} = \dfrac{\partial U}{\partial \eta} \end{cases}$$

where $U = \dfrac{M}{r_1} + \dfrac{m}{r_2}$. r_1 and r_2 are the distances of the infinitesimal body from M and m respectively. The units are so chosen that the Gaussian constant and the distance between the finite bodies are both unity. The motion of the satellite may be referred to axes rotating with the uniform angular velocity n, by making the substitution

$$(2)\qquad \begin{aligned} \xi &= x\cos(nt) - y\sin(nt) \\ \eta &= x\sin(nt) + y\cos(nt) \end{aligned}$$

(1) takes the form

$$\begin{aligned} (\quad)\cos(nt) - [\quad]\sin(nt) &= 0 \\ (\quad)\sin(nt) + [\quad]\cos(nt) &= 0 \end{aligned}$$

Eliminating $\cos(nt)$ and $\sin(nt)$ we find explicitly

$$(3)\qquad \begin{cases} \dfrac{d^2x}{dt^2} - 2n\dfrac{dy}{dt} = n^2x + \dfrac{\partial U}{\partial x} \\[2ex] \dfrac{d^2y}{dt^2} + 2n\dfrac{dx}{dt} = n^2y + \dfrac{\partial U}{\partial y} \end{cases}$$

Suppose that n is the mean motion of the planet and the star around their center of gravity, and that the axes have been so chosen that the x-axis passes through their centers. Then we have $n^2 = M + m$ and Jacobi's integral can at once be found.

$$(4)\qquad \left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 = V^2 = n^2(x^2+y^2) + \frac{2M}{r_1} + \frac{2m}{r_2} - C$$

$-C$ is the constant of integration and V the velocity of the infinitesimal body referred to the rotating axes. This integral is an invariant relation between the square of the velocity of the satellite with respect to the rotating axes and its coordinates, and will be fulfilled therefore for all configurations of the system. If V is chosen arbitrarily the locus of points where the satellite will move with that velocity is given by (4); and conversely, (4) furnishes the velocity with which the infinitesimal body will move at any point in the plane. In particular, if V be chosen equal to zero, (4) will give the curves where the satellite's velocity will be zero; and these curves separate those portions of the rotating plane where the infinitesimal body may move from those where it cannot.

The discussion of the forms of these curves was given by Dr. Hill in his celebrated papers on the Lunar Theory in the first volume of the *American Journal of Mathematics*. Later treatments, somewhat modified in the details, have been given by Bohlin and Darwin in the 10th and 21st volumes of the *Acta Mathematica* respectively, and by Poincaré in the 3d volume of his *Méthodes Nouvelles de la Mécanique Céleste*. Therefore, it will be sufficient here to announce the results needed without going into the details of the demonstrations.

When $V = 0$ (4) becomes

$$n^2(x^2+y^2) + \frac{2M}{r_1} + \frac{2m}{r_2} = C \qquad (5)$$

Suppose the distances of M and m from the origin are respectively x_1 and x_2, then $r_1 = \sqrt{(x-x_1)^2+y^2}$, and $r_2 = \sqrt{(x-x_2)^2+y^2}$. For sufficiently large values of C (5) is the equation of an oval roughly elliptical in shape, around each of the bodies M and m, and of a much larger one enclosing both of the small ones. The satellite may move inside of either of the small ovals or outside of the large one. In all other parts of the plane the velocity will be imaginary. Since these branches are all closed the infinitesimal body will always remain in the one of these three regions in which it is at the origin of time. It is of interest to note that it is precisely under the limitations here made that Dr. Hill proved that the radius vector of the moon's orbit could never surpass a certain value.

For smaller values of C the small ovals enlarge, and for a definite value of C unite, forming an hour-glass shaped figure. Under these circumstances there is an avenue for the passage of the infinitesimal body from the planet to the star. The question whether in all non-periodic orbits the infinitesimal body would necessarily pass from one oval to the other has not been settled. Darwin, however, speaking of this point in his memoir on Periodic Orbits, *Acta Mathematica*, Vol. I, p. 170, says, "It seems likely that a body of this kind would in course of time find itself in every part of the space within which its motion is confined." If the neck of the hour-glass is large the passage from one oval to the other is assured, and that in a very short time. In such a case as this we shall say that the satellite motion is not temporarily stable. To make the phrasing strictly in harmony with the statement of our problem and the definitions already given, we shall say that, when the satellite is revolving around the planet in an orbit larger than that small oval which first touches the small oval around the star, the satellite motion is not temporarily stable. This puts the problem in such a form that the numerical treatment is very simple.

Before considering the details of this point it may be remarked that for still smaller values of C the oval around the planet unites with the large oval so that the region of imaginary velocity has the shape of a horse-shoe with the toe at superior conjunction with the star. If the initial conditions are such that the curves of zero velocity assume this form the satellite motion is much more unstable. For a still smaller value of C the locus shrinks to two points

forming equilateral triangles with M and m. This is the minimum value of C for which (5) can be written in real quantities.

There are two direct methods of finding whether the satellite motion is temporarily stable as defined above. The first is to find the value of C for which the locus takes the form of an hour-glass, and then find whether the C determined by the initial conditions is larger or smaller. The second is to construct the small oval around the planet which first touches the one around the star, and then find if the supposed orbit of the satellite passes outside of this curve.

In order to solve these problems it will be convenient to express (5) entirely in terms of r_1 and r_2 as variables.

Let $x^2 + y^2 = R^2$, then we have

$$y^2 = r_1^2 - (x - x_1)^2$$
$$y^2 = R^2 - x^2$$
$$y^2 = r_2^2 - (x - x_2)^2$$
$$x_1 = \frac{m}{M+m}\quad,\quad x_2 = \frac{M}{M+m}$$

Eliminating y^2 and x we find

$$R^2 = Mr_1^2 + mr_2^2 - Mm$$

Then, since $n^2 = M + m$, we may write (5)

$$M\left(r_1^2 + \frac{2}{r_1}\right) + m\left(r_2^2 + \frac{2}{r_2}\right) = C' \tag{6}$$

When the two small ovals first touch we have for the point of contact $r_1 = 1 - r_2$; hence (6) becomes

$$M\left\{(1-r_2)^2 + \frac{2}{1-r_2}\right\} + m\left(r_2^2 + \frac{2}{r_2}\right) = C' \tag{7}$$

This equation must have a double root, therefore we may place the first derivative of it with respect to r_2 equal to zero. Performing the differentiation and clearing of fractions we have

$$\begin{aligned}(M+m)\,r_2^5 - (3M+2m)\,r_2^4 \\ + (3M+m)\,r_2^3 - mr_2^2 + 2mr_2 - 1 = 0\end{aligned} \tag{8}$$

If we determine r_2 from this equation and substitute it in (7) we shall have the value of C' for which the small ovals have a point of contact. If the C' determined from the initial conditions is smaller than this the satellite motion is not temporarily stable.

Using the value of C' obtained from (7) the ovals may all be computed from (6). Assuming values of r_2 arbitrarily, the values of r_1 which will satisfy (6) can be found by the solution of a cubic. Let

$$a = \frac{m}{M}\left(r_2^2 + \frac{2}{r^2}\right) - \frac{C'}{M}$$

then (6) may be written

$$r_1^3 + ar_1 + 2 = 0 \tag{9}$$

The real positive roots of this equation are the only ones that have a meaning in our problem. It is easy to see that a is essentially negative for all values of r_2 consistent with (6); therefore the necessary and sufficient condition that (9) shall have a real positive root is that

$$-a > 3$$

Expressing a in terms of r_2 we have for the limiting value of this inequality

$$m\left(r_2^2 + \frac{2}{r_2}\right) - C' + 3M = 0$$

This is of the same form as (6), and may be written

$$r_2^3 + a' r_2 + 2 = 0 \tag{10}$$

where
$$a' = \frac{1}{m}(3M - C')$$

Suppose the roots of (10) are r_{21}, r_{22} and r_{23}. If we define the auxiliary angle θ by $\sin\theta = \sqrt{\frac{27}{-a'^3}}$, where $\theta \leq \frac{\Pi}{2}$, we shall have

$$\left.\begin{aligned} r_{21} &= 2\sqrt{\frac{-a'}{3}}\sin\frac{\theta}{3} \\ r_{22} &= 2\sqrt{\frac{-a'}{3}}\sin\left(60^\circ - \frac{\theta}{3}\right) \\ r_{23} &= -2\sqrt{\frac{-a'}{3}}\sin\left(60^\circ + \frac{\theta}{3}\right)\end{aligned}\right\} \tag{11}$$

If $-a' \geq 3$, then r_{21} and r_{22} are real and positive, and all other values of r_2 for which real positive values of r_1 can be found satisfying (6) lie between them. Hence r_{21} is the minimum distance from m to the small oval around it, and if the infinitesimal body is everywhere at a greater distance from the planet than this quantity, the satellite motion is certainly not temporarily stable. If it is supposed that the satellite moves in every part of its orbit with considerable relative velocity, the limit assigned by this method will be much greater than that by comparing constants, and the instability of a body moving beyond this limit consequently more marked.

If in any case the hypothesis places the supposed unseen body beyond the limit determined by either one of these two methods the satellite motion is not even temporarily stable. The hypothesis must then be abandoned unless it is equally efficient in explaining the phenomena with the unseen body attending one of the known stars for a time, and then the other.

It must be stated that there are certain *periodic* solutions beyond the limits just mentioned, where the infinitesimal body describes closed curves around the planet. For regions near these limits they have been discussed in detail

by DARWIN in his memoir in *Acta Mathematica*, Vol. 21. They are of fantastic shapes, nearly all containing loops, and have very large moduli of instability. They would be impossible in a system where there were tides, or where the two finite bodies were not exactly spheres of homogeneous concentric layers. Besides, the probability that the initial conditions would be exactly such as to start that kind of a system is infinitely small.

II. APPLICATION TO THE BINARY SYSTEM, F. 70 *Ophiuchi.*

The most conspicuous example of the hypothesis of an unseen body which has not been confirmed by direct observations, is that proposed by Dr. T. J. J. SEE to account for certain apparent irregularities in the motion of the binary system, F. 70 *Ophiuchi.* The hypothesis was first made public in a preliminary announcement in *A. J.* No. 358, which was soon followed in *A.J.* No. 363 by an elaborate paper on the subject. The numerical work was carried out by Mr. ERIC DOOLITTLE and there can be no question of its correctness. Mr. DOOLITTLE has since undertaken in *A.J.* No. 400 to explain the motion without the assumption of the existence of a third body in the system and has succeeded in bringing theory and the observations into reasonable accord.

In this paper we are only interested in the consequences of the hypotheses made, so we shall pass at once to the conclusions reached by Dr. SEE. He found that the visible companion revolves around the primary in a period of about 88 years, in an orbit approximately an ellipse with an eccentricity of 0.5. He assumed that the companion is attended by a dark satellite having a period of 36 years. He stated that the center of gravity of the companion and satellite moves in an ellipse with a major semi-axis of 4″.548, and that the bright companion describes a curve around this center of gravity with a radius of 0″.3. Under these assumptions a very satisfactory agreement between theory and observation was obtained.

One cannot but be struck with the relatively long period of the dark satellite. There is no observed case where there is anywhere nearly such an approach to equality between the period of a satellite and that of the planet around which it revolves. In Dr. HILL'S "Moon of Maximum Lunation" there is a near approach to the ratio of periods assumed by Dr. SEE, but that cannot be taken as throwing much light upon the subject since for other purposes in his investigation he had neglected the solar parallax. It is precisely in this case that the restriction imposed by Dr. HILL is most effective in modifying the results, since the moon is near quadrature during a large part of its period. DARWIN found a few extreme cases where the period of the satellite was nearly half that of the planet, but in all of them there are loops and parts of the orbit where the satellite moves very slowly. In addition the orbits are *very unstable.* These considerations throw a strong doubt upon the possibility of a satellite's moving according to the hypothesis.

Let us apply the tests developed above numerically in this case. Let M represent the mass of the primary, m_1 that of the companion and m_2 that of the supposed dark star. Since we neglect the eccentricity, which is 0.5, it will be seen that we are taking a system where the perturbations, arising from the action of the principal star, are *very much less* than in the actual case when the companion is in periastron. We assume that the center of gravity of the companion and satellite describes a circle which will be very nearly true, after having neglected the eccentricity, if the satellite motion is stable. In accordance with the development of our formulas the radius of this circle is the unit of length. Letting P and P' represent the periods of the companion and satellite respectively, and a' the mean distance of the satellite from the companion, we have with sufficient approximation

$$\frac{M + m_1 + m_2}{m_1 + m_2} = \frac{P'^2}{P^2 a'^3}$$

$P' = 36$ yrs. and $P = 88.4$ yrs. The value of a' depends upon the relative masses of m_1 and m_2 and the distance of m_1 from the center of gravity of the two. The distance of m_1 from the center of gravity was found by Dr. SEE to be 0″.3. We shall favor the result of stability if we take a' as small as possible. It is evident that a' will become smaller the larger we assume m_2 to be. It seems to be a very liberal assumption to suppose that m_2 is equal to m_1 in mass, when it is remembered that it was so faint as to be absolutely invisible to BURNHAM with both the 18-inch telescope of the Dearborn Observatory and the 36-inch telescope of the Lick Observatory. Nevertheless, let us take the extreme case and suppose that the visible companion is a mere particle describing an orbit around the unseen body. By this assumption the perturbations arising from the action of the primary are again *very much less* than they would be in the actual system.

Suppose we take m_2 for the unit of mass then we find from the equation last written, $M = 577$. This is undoubtedly much too large a mass relatively, for the primary, and results from our attempts to favor the conclusion of stability. Now solving (8) for that value of r_2 for which the small ovals unite, we find $r_2 = 0.081$. Substituting this in (7) we find that the critical value of C' is, $C' = 1768$. Computing the minimum value of r_2 by (11) we find, $r_2 = 0.0531$. The corresponding value of r_1 is unity, hence it is seen that the critical curve of zero velocity has its minimum distance from the center of gravity of the companion and dark body, nearly in quadrature. But the hypothesis explicitly supposes that when the bright com-

panion is in quadrature from the center of gravity, it is displaced by 0″.3 or 0.066 in our units. Since this is far beyond the limit just found we are led to the conclusion that *there is no dark star in the binary system* F. 70 *Ophiuchi permanently revolving around the companion with a period of 36 years, and of such a mass that the observed companion is at a distance of* 0″.3 *from where it would be if it were undisturbed.*

It might be of some interest to know how many revolutions the body would make before passing to the primary, if it were started as the hypothesis states it must be moving. Retaining the limitations introduced, it would be a simple although lengthy task to decide the question by the use of mechanical quadratures, but it has hardly seemed of sufficient interest to justify the labor. DARWIN has treated some cases so near like this that pretty safe conclusions can be drawn from his results without going to the actual computation.

If we take the initial conditions in accordance with the hypothesis, and construct the curve of zero velocity we shall find the region of imaginary velocity has reduced to a very narrow horse-shoe. (For brevity the details, which are simple, are omitted here). The body may move anywhere else in the plane. DARWIN has considered no case in *Acta Mathematica*, Vol. 21, so unfavorable to temporary stability of satellite motion as this one, but taking the one most nearly similar we are able to get a fair idea of the way the body will move. A little computation shows that the curve in Fig. 3, p. 173, *loc. cit.*, marked $x_0 = 1.12$, has much the same initial conditions as we have in our problem. After one revolution it is nearly the same as the curve marked $x_0 = 1.09$ in Fig. 5, which at once passes away to the principal star. From this we may conclude that the companion and dark satellite would not make more than one revolution around their center of gravity before one of them would pass away to the large star.

The difficulties for the hypothesis here encountered might be avoided if the period of the unseen body could be reduced to a very few years, but there is no observational basis for such a supposition. Or the perturbations of the companion might be supposed to be very much less than 0″.3, but in that case the reality of their existence at all would be improbable.

The University of Chicago, 1899 *April.*

OBSERVATIONS OF ASTEROIDS AND COMETS,

MADE AT THE SAYRE OBSERVATORY, SO. BETHLEHEM, PA.,

By JOHN H. OGBURN.

Bethlehem M.T.	✱	No. Comp.	Object — ✱ Δα	Object — ✱ Δδ	Object's Apparent α	Object's Apparent δ	log pΔ for α	log pΔ for δ
			COMET 1898 X.					
1898 Nov. 7 6h 58m 23s	1	5 , 8	+2m 7.61s	+0′ 14.7″	17h 41m 48.55s	+14° 27′ 32.5″	9.628	0.688
11 6 52 4	2	5 , 6	+0 40.23	+5 8.7	17 52 0.00	+ 7 51 0.0	9.616	0.734
12 6 43 40	3	8 , 6	+0 26.68	−1 29.2	17 54 57.99	+ 6 24 10.5	9.618	0.732
			Fortuna (19).					
Oct. 6 9 32 29	4	8 , 5	+0 47.78	+2 48.1	0 48 16.21	+ 6 9 59.4	n9.392	0.707
8 9 54 55	5	4	+2 6.33	+5 19.3	0 46 34.58	+ 5 56 55.3	n9.283	0.705
9 8 5 32	5	5 , 4	+1 19.99	−0 41.3	0 45 48.25	+ 5 50 54.7	n9.547	0.722
19 9 4 49	6	4	−1 39.13	+4 19.7	0 37 55.38	+ 4 48 6.2	n9.275	0.716
20 8 9 40	7	4	+2 6.12	−1 10.4	0 37 14.34	+ 4 42 34.0	n9.438	0.722
22 9 31 59	8	3	+2 59.41	−3 27.2	0 35 51.31	+ 4 31 4.1	n9.050	0.716
			Hebe (6).					
1897 Nov. 27 9 24 20	9	9 , 6	+0 10.36	−2 41.9	5 6 23.30	− 2 39 34.1	n9.525	0.773
28 8 34 11	9	8 , 4	−0 47.15	−1 30.4	5 5 25.80	− 2 38 22.7	n9.588	0.769
Dec. 8 8 29 14	10	10 , 7	−0 16.49	+5 13.7	4 55 16.96	− 2 7 42.6	n9.532	0.770
			COMET *a* 1899 (SWIFT).					
1899 Mar. 12 7 43 29	11	5	+3 23.66	+5 12.7	3 9 59.56	−16 19 12.9	9.638	0.792
16 7 12 31	12	11	−0 1.87	+4 20.7	2 55 27.00	−11 47 18.8	9.616	0.793
17 7 15 40	13	11	+2 49.55	+7 8.2	2 52 4.35	−10 44 7.5	9.620	0.788

Mean Places for 1897.0, 1898.0 and 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	17 39 38.79	+2.15	+14 27 14.6	+ 3.2	½ (Harvard Mer. Cir. + Pulkowa '55)
2	17 32 0.00	+2.30	+ 7 46 0.0	+ 4.1	DM. +7°3511
3	17 54 28.97	+2.34	+ 6 25 35.6	+ 4.1	Munich I, 15106
4	0 47 23.82	+4.61	+ 6 6 41.5	+29.8	Yarnall 453
5	0 44 23.63	+4.62	+ 5 51 6.1	+29.9	Göttingen 255
6	0 39 29.88	+4.63	+ 4 43 16.4	+30.1	Boss, Albany A.G. Catal. 176
7	0 35 3.30	+4.62	+ 4 43 14.2	+30.2	Boss, Albany A.G. Catal. 145
8	0 32 47.27	+4.63	+ 4 34 1.0	+30.3	Boss, Albany A.G. Catal. 135
9	5 6 8.03	+4.91	− 2 37 5.0	+12.8	Gould's Gen. Catal. 5936
10	4 55 28.40	+5.05	− 2 13 8.6	+12.3	Gould's Gen. Catal. 5692
11	3 6 35.10	+0.80	−16 24 22.1	− 3.5	Gould's A.C. 3436
12	2 55 28.14	+0.73	−11 51 37.7	− 1.8	W. Bessel 942
13	2 49 14.07	+0.73	−10 51 14.3	− 1.4	½ (G A.C. 3093 + Brussels 1126)

OBSERVATIONS OF COMET 1898 I,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY,

BY WILLIAM J. HUSSEY.

1898 Mt. Hamilton M.T.		*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Mar. 21	17 10 3	1	15 , 9	−1 3.48	+9 31.3	21 25 59.75	+18 49 16.8	n9.647	0.605
22	16 29 13	2	10 , 8	+3 7.32	−0 32.5	21 29 37.50	+19 49 50.9	n9.679	0.637
26	16 52 49	3	12 , 8	+1 34.58	−1 15.3	21 45 6.42	+23 58 7.5	n9.676	0.578
27	16 0 21	4	8 , 8*	−0 15.03	+5 2.7	21 48 56.90	+24 56 57.6	n9.707	0.640
	16 20 34	5	10 , 8*	−0 29.22	+1 28.2	21 49 0.33	+24 57 44.9	n9.699	0.613
28	16 35 52	6	4	. . . .	+1 20.4	. . . . .	+25 59 4.1	. .	0.585
	17 4 46	7	10 , 10*	−0 15.40	−2 49.5	21 53 9.73	+26 0 16.4	n9.673	0.542
29	16 17 14	8	9 , 8	−1 5.53	−4 7.3	21 57 6.85	+26 58 25.9	n9.708	0.606
30	16 9 43	10	12 , 8	−1 31.89	+1 9.9	22 1 14.17	+27 57 40.9	n9.715	0.609
31	15 56 43	11	8 , 8	−0 55.76	+2 33.3	22 5 23.72	+28 56 8.3	n9.724	0.625
Apr. 2	16 17 45	12	10 , 8	+0 59.38	+0 27.4	22 14 0.49	+30 52 52.1	n9.725	0.575
	16 45 4	13	10 , 8	+0 51.16	−4 46.0	22 14 5.26	+30 53 57.6	n9.710	0.525
3	16 51 21	14	6	. . . .	−4 46.1	. . . . .	+31 51 1.5	. .	0.502
4	16 34 5	15	8 , 8*	+0 5.92	−5 51.7	22 22 50.58	+32 46 24.3	n9.726	0.528
6	15 45 21	17	8 , 8*	−0 31.90	−2 29.2	22 31 41.17	+34 33 53.2	n9.753	0.611
8	16 19 28	18	10 , 10*	+0 10.16	−1 52.4	22 41 1.02	+36 20 48.6	n9.753	0.532
15	16 34 44	19	8 , 7	+2 11.30	−4 24.0	23 15 2.53	+41 57 8.7	n9.795	0.448
16	15 43 46	20	8 , 8	+1 2.73	+3 0.4	23 19 54.51	+42 38 52.1	n9.803	0.577
18	14 51 52	21	8 , 8	+2 13.10	−5 11.4	23 29 57.54	+44 0 24.6	n9.803	0.682
20	16 24 53	22	10 , 8	+1 43.40	−1 5.7	23 40 42.28	+45 21 0.7	n9.815	0.448
21	16 45 21	23	3	. . . .	+3 9.8	. . . . .	+45 58 39.0	. .	0.373
22	15 47 50	24	10 , 10*	+0 10.61	−8 1.4	23 51 6.99	+46 33 1.1	n9.822	0.555
	16 1 59	25	4*	. . . .	−3 22.5	. . . . .	+46 33 18.6	. .	0.512
	16 16 25	24	8 , 8*	+0 16.90	−7 17.9	23 51 13.28	+46 33 44.6	n9.828	0.470
26	15 59 16	26	4 , 3	+2 13.11	−1 36.8	0 12 36.95	+48 44 9.1	n9.849	0.519
28	14 42 2	27	10 , 8	−2 2.18	−1 10.9	0 23 10.65	+49 40 40.7	n9.837	0.719
May 2	15 13 20	28	10 , 10	+1 22.02	−0 26.0	0 45 7.61	+51 23 0.4	n9.860	0.671
3	15 1 2	29	8 , 8*	−0 12.97	+2 48.2	0 50 32.61	+51 45 21.0	n9.863	0.672
	15 31 17	29	8 , 8*	−0 6.07	+3 16.6	0 50 39.51	+51 45 49.4	n9.874	0.408
4	15 10 2	31	10 , 10*	−0 5.09	−4 11.9	0 56 2.28	+52 6 54.7	n9.870	0.655
9	15 39 41	33	10 , 10*	+0 12.89	−3 21.4	1 23 15.07	+53 38 24.0	n9.893	0.590
	16 4 16	34	4	. . . .	+1 24.1	. . . . .	+53 38 39.9	. .	0.517
10	14 53 47	35	10 , 10	+2 23.96	−4 24.6	1 28 26.39	+53 53 7.2	n9.874	0.700
17	15 1 14	36	10 , 6	−2 56.22	−1 24.7	2 5 2.47	+55 14 53.7	n9.887	0.697
19	15 49 23	37	8 , 8*	−0 12.08	+2 17.7	2 15 15.71	+55 31 24.1	n9.901	0.584
23	15 11 54	39	8 , 8*	+0 51.28	+5 35.2	2 34 37.50	+55 55 31.5	n9.898	0.683

Mean Places for 1898.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 27 2.81	+0.42	+18 39 51.4	−5.9	Auwers, Berlin A.G. Catal. 8779
2	21 26 29.77	+0.41	+19 50 29.5	−6.1	" " " 8776
3	21 43 31.48	+0.36	+23 59 28.4	−5.6	Becker, Berlin " 8406
4	21 49 11.58	+0.35	+24 52 0.5	−5.6	" " " 8446
5	21 49 29.20	+0.35	+24 56 22.3	−5.6	" " " 8447
6	21 51 41.05	+0.35	+25 57 49.3	−5.6	Graham, Cambridge " 13020
7	21 53 24.79	+0.34	+26 3 11.4	−5.5	" " " 13050
8	21 58 12.05	+0.33	+27 2 38.5	−5.3	Connected with *9
9	21 58 13.75	+0.32	+27 7 32.4	−5.3	Graham, Cambridge A.G. Catal. 13132
10	22 2 45.74	+0.32	+27 56 36.2	−5.2	" " " 13203
11	22 6 19.17	+0.31	+28 53 40.1	−5.1	" " " 13251
12	22 13 0.83	+0.28	+30 52 29.8	−5.1	Leiden, A.G. Zones, 3 and 4
13	22 13 13.82	+0.28	+30 58 48.7	−5.1	" " 6 and 114
14	22 20 0.11	+0.25	+31 55 52.4	−4.8	" " 7 and 9
15	22 22 44.42	+0.24	+32 52 20.8	−4.8	Connected with *16
16	22 22 43.02	+0.23	+32 59 42.9	−4.8	Leiden A.G.Zones, 117 and 120
17	22 32 12.86	+0.21	+34 36 26.9	−4.5	" " 89 and 93
18	22 40 50.68	+0.18	+36 22 45.1	−4.1	Lund A.G. Zones, 289 and 329
19	23 12 51.09	+0.14	+42 1 35.6	−2.9	Deichmüller, Bonn A.G. Catal. 17625
20	23 18 51.66	+0.12	+42 35 54.2	−2.5	" " " 17727
21	23 27 44.34	+0.10	+44 5 38.4	−2.4	" " " 17898
22	23 38 58.79	+0.09	+45 22 8.3	−1.9	" " " 18095
23	23 47 45.65	+0.07	+45 55 30.3	−1.1	" " " 18231
24	23 50 56.31	+0.07	+46 41 3.9	−1.4	" " " 18284
25	23 50 12.98	+0.07	+46 36 42.5	−1.4	" " " 18266
26	0 10 23.75	+0.09	+48 15 46.4	−0.5	" " " 155
27	0 25 12.73	+0.10	+49 41 51.4	+0.2	" " " 376
28	0 43 45.47	+0.12	+51 23 25.7	+0.7	Rogers, Cambridge A.G. Catal. 359
29	0 50 45.45	+0.13	+51 42 31.9	+0.9	Connected with *30
30	0 51 25.86	+0.13	+51 41 17.9	+0.9	Rogers, Cambridge A.G. Catal. 425
31	0 56 7.23	+0.14	+52 11 5.5	+1.1	Connected with *32
32	0 56 40.37	+0.13	+52 18 8.8	+1.1	Rogers, Cambridge A.G. Catal. 472
33	1 23 1.92	+0.26	+53 41 43.4	+2.0	" " " 661
34	1 24 0.38	+0.26	+53 37 13.8	+2.0	" " " 673
35	1 26 2.14	+0.29	+53 57 29.8	+2.0	" " " 683
36	2 7 58.26	+0.43	+55 16 15.1	+3.0	Krueger, Helsingfors-Gotha A.G. Catal. 1995
37	2 15 27.29	+0.50	+55 29 3.4	+3.0	Connected with *38
38	2 15 14.65	+0.50	+55 22 44.4	+3.0	Krueger, Helsingfors-Gotha A.G. Catal. 2168
39	2 33 45.60	+0.62	+55 49 52.9	+3.4	" " " " 2420

An asterisk in connection with the number of comparisons indicates direct micrometer measures. I am indebted to Mr. CODDINGTON for assistance in reducing the observations.

Mt. Hamilton, California, 1899 *April* 21.

OBSERVATIONS OF COMET 1898 VIII,

BY F. K. BUTTERS.

The two plates, measured, were positive from negatives taken by Dr. H. C. WILSON of Goodsell Observatory, with his six-inch camera, while photographing the Leonid meteors. The first plate was exposed Nov. 14, $14^h 10^m$–$16^h 0^m$, Central Standard Time; the second, Nov. 14, $16^h 10^m$–$17^h 50^m$. The scale value of the plates is large, 1mm. = 227″. In measuring the plates the position of the comet was assumed as the center of the plate, and the corrections obtained for this value were thus applied directly to the position of the comet. The first plate was reduced by Mr. J. G. ANDERSON, the second by myself. The observations of right-ascension are less accurate than those of declination on account of the blurring caused by the motion of the comet in right-ascension. The places are for the beginning of the year.

1898 Central St. T.		☄ (1898.0) α	δ	log $p\Delta$ for α	for δ
	h m	h m s	° ′ ″		
Nov. 14	15 5	10 7 9.77	22 56 59.9	n9.568	0.625
14	17 0	10 7 17.70	22 57 11.7	n9.291	0.535

Mean Places for 1898.0 of Comparison-Stars.

*	α	δ	Authority
	h m s	° ′ ″	
1	10 6 40.57	+22 42 51.7	Becker, Berlin A.G. Catal. 3957
2	10 6 43.13	+22 52 20.6	" " " " 3958
3	10 7 24.84	+23 22 21.5	" " " " 3961
4	10 8 30.51	+23 17 17.1	" " " " 3963

University of Minnesota, Minneapolis, Minn., 1899 *April* 1.

OCCULTATIONS OBSERVED DURING THE LUNAR ECLIPSE, 1898 DEC. 27,

By C. L. DOOLITTLE.

The observations which follow were made by myself with the 18-inch equatorial of this observatory. The magnifying power employed was 200.

The sidereal time of observation was recorded by chronograph, corrected with the standard clock. As a check, and also a precaution against failure of chronographic record, Mr. Eric Doolittle also recorded the time by means of a chronometer, a signal being given when the key was pressed. This chronometer was compared with the clock before and after observation. Clouds seriously interfered with the work.

The numbers of the stars are those of the Pulkowa Circular.

Star		Chronometer	Clock	
		h m s	h m s	
79	Ingress	1 1 40.37	1 1 40.46	Very faint
84	Ingress	1 21 26.17	1 21 26.08	
72	Egress	1 23 41.37	23 40.51	Uncertain
92	Ingress	1 25 6.47	25 6.36	
Anon.	Ingress	1 30 37.17	30 37.09	
87	Ingress	1 28 59.67	28 59.60	
75	Egress	1 32 7.67	. . . .	Probably late
88	Ingress	1 35 48.67	35 48.66	
78	Egress	1 43 43.77	43 43.71	
96	Ingress	1 46 48.87	46 48.64	
80	Egress	1 50 33.17	1 50 33.38	
89	Egress	2 4 14.87	. . . .	

Latitude of instrument 39° 58′ 2″. Longitude $7^m\ 5^s.4$ E. of Washington. Elevation above mean sea level 266.8 feet.

Flower Observatory, University of Pennsylvania.

COMET c 1899 = 1873 II.

A dispatch from Prof. J. E. Keeler, Director of the Lick Observatory, to the Harvard College Observatory, states that Tempel's comet, 1873 II, was observed by Perrine in the position

1899 May 6.9077 Gr. M.T., $\alpha = 18^h\ 52^m\ 57^s.8$, $\delta = -4°\ 32'\ 19''$. It is described as faint.

The above observation shows that the correction required by Schulhof's ephemeris (*A.N.* 3554) is only $-6^s.4$ in α, and $-9''$ in δ. — Ed.

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MICROMETRICAL MEASURES OF THE SATELLITE OF *NEPTUNE* DURING THE OPPOSITION OF 1898-99 WITH THE 40-INCH REFRACTOR OF THE YERKES OBSERVATORY, WITH SOME REMARKS ON TEMPERATURE CHANGES IN THE OBJECT-GLASS,

By E. E. BARNARD.

The following measures of the position of the satellite of *Neptune* are a continuation of those previously printed in *A.J.* 436.

An unfortunate sickness, and much bad weather, prevented the series of measures being as complete as I had intended. The number of nights on which the satellite was observed (52), however, is one greater than for the measures of 1897-98.

The past winter has been a very hard one here — one of the worst known to this section of the country. The temperature kept very low most of the time and the seeing was bad. On several occasions the measures were repeated as the images had somewhat improved. The parallel has been determined immediately at the close of the measures by *Neptune* itself, the mean of from three to five settings being used. The measures are otherwise uncorrected for refraction, such correction being essentially insensible in the distances.

The mechanical portion of the telescope has performed well during the extremely cold weather. The clock served well down to a temperature of 12° or 15° below zero, after which it slowed up, more or less interfering with the measures. In the low temperatures the telescope seemed to be as easily moved by hand as at any time, and the micrometer worked with perfect satisfaction.

The electric illumination supplied the micrometer by WARNER and SWASEY has been used altogether to the exclusion of the oil lamp. It works very satisfactorily except when the wires are widely separated, when a deficiency of illumination occurs in the case of the distant wire, but this is objectionable only where one of the objects is rather faint. This defect can doubtless be remedied by placing the lamp further from the micrometer box and using a stronger light.

The canvas curtain which serves as a wind break in the observing slit, has been of the greatest value in protecting the telescope from the wind.

The great telescope seems to be remarkably stable in its different parts. The object-glass sensibly changes in figure by the great changes of temperature to which it has been subjected. This is shown by the measures of the difference of declination between *Atlas* and *Pleione* of the *Pleiades*. In the fall of 1897 a series of measures of these stars was commenced to show what changes were produced in the great instrument by changes of temperature during summer and winter.

The intense cold of the past winter has afforded an excellent opportunity to test the subject, as measures of the stars were obtained with temperatures as low as 22° below zero (F). The highest temperature last fall, during the measures, was +80° (F). The measures of these stars have therefore been made with a range of 102° of temperature.

During the observations the temperature and scale-readings of the focusing tube were recorded. From these the changes that took place in the telescope can be investigated. A brief summary of the results so far obtained, may be of interest just now. It is intended, however, to continue the measures through another season, for it is probable that the changes will not exactly repeat themselves under identical conditions of temperature.

I have taken some of the observations made during the hot weather of last summer and fall, and compared them with some of the measures made during the cold of winter, as shown below:

	Mean Temp. F	Mean Scale read'g	$\Delta\delta$	
	°	inches	"	
July 26-Sept. 3, 1898	72.81	2.269	0.676	(10 nights)
Jan. 28-Feb. 12, 1899	−10.17	2.011	0.491	(9 nights)
	82.98	0.258	0.185	

(In the $\Delta\delta$ I have omitted 31 complete revolutions of the screw.)

The changes in the focus and measured distance were very marked as the cold weather came on, and the above results are in no wise accidental.

From these it will be seen that the focus of the object-glass shortened 0.26 in. more than did the tube itself. It will also be seen that the distance between the two stars lessened by nearly 0″.2 and this change must be attributed to change in the micrometer-screw and in the focus of the object-glass, since the stars would be essentially fixed during the period covered by the observations.

Assuming a uniform value for the revolution of the micrometer-screw (9″.677), the shortening of the focus of the object-glass would have made the measures less in winter, while the contraction of the micrometer-screw alone would have made them larger. At each observation the stars were carefully focused; we can, therefore, neglect the change in the length of the steel tube, except for determining the total change in the focus of the object-glass.

The steel tube would shorten about 0.44 in. in the measures cited. The total shortening therefore of the focus of the 40-inch would be 0.70 in. and this would produce a change of about 0″.27 in the measures, making the winter measures that much smaller. The contraction of the micrometer-screw would produce an increase in the distance of about 0″.17, which is to be taken from the above value, leaving 0″.10 as the lessening of the distance-measures of the two stars from the shortening of the focus and the contraction of the micrometer-screw. We can, therefore, account for the difference between the summer and the winter measures to the extent of 0″.10, which leaves only 0″.08 to be attributed to error of observation.

The extreme range of temperature in the observations of 1898–99, was from +80° F to −22° F or 102°. The range of focus readings was from 2.35 inches to 1.97 inch, or 0.38 inch, while the range of the measures was from 0″.84 to 0″.31 = 0″.53, covered by 44 nights from 1898 July 26 to 1899 April 4.

It would seem from the foregoing considerations that a large glass in a severe climate like this is subject to considerable change of figure, which would interfere with very exact work, such as for parallax, if not strictly taken into account. It is probable, also, that the molecular change in the object-glass may prevent these changes from repeating themselves under the same conditions of temperature. I am rather led to this belief by the measures of *Atlas* and *Pleione* during the fall and winter of 1897. At that time the measures were carried over the interval from 1897 Aug. 27 to 1898 Jan. 1 through a range of 49° of temperature. During the measures of that season, it was clearly shown that the apparent distance between the stars distinctly increased to the extent of 0″.2 or 0″.3 as the cold weather came on.

Careful determinations of the color-curve of the great object-glass have been spectroscopically made by Professor Frost and Mr. Ellerman during wide extremes of temperature, and the changes due to temperature, in this direction, are now being investigated by Professor Frost, and the results when combined with the visual investigations must be of very great interest and importance.

Micrometrical Measures of the Satellite.

90th Meridian Time 1898	P.A.	Comp.	Distance	Comp.	Remarks
	°		″		
Aug. 29 15 25 12	87.12	4			Faint
15 31 8			16.10	4	
15 35 59			15.76	4	
30 15 7 3	46.14	4			Faint and blurred
15 13 44			14.02	4	
15 17 45			13.91	4	
31 15 7 32	325.67	4			
15 13 12			10.54	4	
15 18 28			10.53	5	
Sept. 1 14 30 2	267.20	4			
14 35 56			15.13	4	
14 39 26			15.47	4	
2 14 12 55	226.72	5			Difficult
14 19 30			13.60	4	
14 23 9			13.58	4	
14 42 36	224.62	4			Obs'ns repeated as the satellite was better seen
14 47 43			13.72	3	
14 50 18			13.44	3	

90th Meridian Time 1898	P.A.	Comp	Distance	Comp.	Remarks
	°		″		
Sept. 3 14 47 38	139.77	5			Seen with the greatest difficulty
14 54 52			10.67	4	
14 59 44			11.11	4	
14 13 51 7	211.04	5			Through breaks in dense clouds
13 56 33			11.86	4	
14 0 45			12.36	5	
20 14 19 28	201.64	6			
14 29 28			11.52	4	
14 34 24			11.17	4	
22 17 2 0	66.72	3			Very faint and difficult in all the measures
17 7 14			16.09	5	
17 12 0	66.25	1			
26 14 10 19	191.48	5			Observations good
14 16 51			10.86	4	
14 21 3			10.90	4	
27 14 9 5	107.02	5			Seen with difficulty
14 16 54			13.84	4	
14 22 9			13.74	4	

90th Meridian Time 1898		P.A.	Comp.	Distance	Comp.	Remarks
	h m s	°		″		
Oct. 10	13 5 51	56.91	6			Faint and difficult
	13 10 24			15.41	4	
	13 14 26			15.57	4	
11	14 15 22	342.96	5			Extremely faint and difficult
	14 27 12			10.82	6	
	15 8 3	338.45	6			Faint, but better seen
	15 14 10			10.62	4	
	15 17 37			10.32	4	
Nov. 7	12 11 4	121.46	4			
	12 16 51			12.61	4	
	12 20 46			13.00	4	
14	18 5 13	60.68	4			Lost in daylight
	18 9 49			15.68	7	
15	10 33 24	19.99	5			
	10 39 50			11.71	5	
	10 43 51			11.82	5	
22	15 37 8	276.90	4			Well seen
	15 41 23			15.24	4	
	15 44 12			15.21	4	
24	9 29 13	187.93	5			Faint, but observations good
	9 34 11			10.91	4	
	9 37 11			11.05	4	
26	9 39 10	62.72	5			Very difficult
	9 45 30			16.23	5	
	9 50 11			16.59	5	
29	12 30 26	236.69	5			Difficult
	12 35 40			15.34	4	
	12 39 14			15.45	4	
Dec. 3	10 3 20	349.51	6			Very difficult
	10 9 18			10.85	4	
	10 12 47			10.03	4	
6	13 37 59	127.97	6			Through thin clouds; faint and difficult
	13 45 17			10.72	4	
	13 49 22			10.87	4	
10	9 29 29	271.66	5			Bright and easy
	9 33 44			15.66	4	
	9 37 26			15.34	4	
11	8 51 8	231.06	5			Observations good
	9 0 42			15.14	4	
	9 3 30			15.10	4	
12	9 20 22	152.20	4			Very difficult
	9 24 55			10.69	4	
	9 27 20			10.66	4	
13	9 0 50	89.02	4			Difficult
	9 6 29			16.77	4	
	9 10 50			16.62	4	

90th Meridian Time 1899		P.A.	Comp.	Distance	Comp.	Remarks
	h m s	°		″		
Jan. 18	8 17 3	61.00	5			
	8 23 14			16.17	4	
	8 26 26			16.30	4	
24	7 55 32	56.57	6			Seeing poor, but obs'ns good
	8 1 52			15.95	4	
	8 4 38			15.76	4	
30	9 58 10	47.83	8			Difficult
	10 6 16			13.95	4	Temperature 17°.0 (F) below zero
	10 10 3			14.43	4	
31	10 34 51	325.30	5			Seeing good; observations good. Temperature 2°.0 below zero
	10 39 6			10.66	4	
	10 41 30			10.76	4	
Feb. 1	9 42 58	299.06	5			Difficult
	9 50 13			11.83	4	
	9 53 29			11.56	4	
6	7 22 42	328.08	5			Difficult
	7 26 54			10.12	4	
	7 30 8			10.32	4	
7	8 40 27	262.36	6			Temperature 3°.0 below zero
	8 46 45			16.36	4	
	8 49 57			16.56	4	
9	9 48 39	132.07	6			Measures difficult
	9 54 28			11.16	4	Temperature 23°.0 below zero
	9 57 17			10.87	4	
10	7 15 4	81.79	5			Temperature 12°.0 below zero
	7 20 29			16.16	3	
	7 23 10			16.52	3	
11	8 33 34	37.45	5			Difficult.
	8 39 47			13.16	4	Temperature 15°.0 below zero
	8 45 7			12.89	4	
12	8 29 14	312.16	4			Observations good
	8 33 33			11.02	4	Temperature 7°.0 below zero
	8 36 56			11.11	4	
13	6 56 12	260.85	5			Seeing very good, but clouds passing
	7 0 24			16.11	4	
	7 4 0			16.33	4	
20	9 9 25	203.94	7			Very faint, through clouds
	9 15 58			11.88	4	
	9 19 29			11.61	4	
	9 27 23	201.15	4			
28	7 47 7	66.98	5			Seeing poor
	7 52 44			16.65	4	
	7 56 59			16.46	4	
Mar. 13	8 57 5	347.09	6			Very difficult
	9 6 20			10.27	5	
	9 13 4			10.39	5	

90th Meridian Time 1899	P.A.	Comp.	Distance	Comp.	Remarks
h m s	°		″		
Mar. 18 7 25 58	53.16	5			Faint and difficult
7 32 16			14.98	4	
7 36 10			14.59	4	
19 7 44 15	339.33	5			Dim
7 51 5			9.94	4	
7 55 6			10.04	4	Better seen
8 4 26	337.91	4			
28 7 58 32	139.82	6			Clouds interfered very much
8 13 11			10.55	4	
8 17 32			10.70	4	
29 7 33 19	82.65	7			
7 38 59			15.74	5	
7 42 30			15.68	5	
7 52 31	81.83	5			
30 8 15 6	39.02	5			Seeing good. Satellite well seen
8 20 5			12.75	4	
8 23 6			12.74	4	
Apr. 3 8 13 50	127.71	5			Very difficult
8 20 35			11.25	4	
8 24 13			11.62	4	
8 27 8			11.33	2	
8 29 49	127.63	3			Better seen; faint

90th Meridian Time 1899	P.A.	Comp.	Distance	Comp.	Remarks
h m s	°		″		
Apr. 4 7 27 45	78.20	6			Seeing very good, and then very bad
7 33 59			15.98	4	
7 37 38			15.83	4	
7 55 48	77.01	4			In this last set seeing was fair
7 59 47			16.08	3	
8 1 47			15.97	3	
7 7 41 8	254.65	5			Clouds interfered; satellite faint
8 17 34			16.32	4	
8 21 31			16.06	5	
8 30 7	253.09	5			
17 7 38 0	15.79	7			
7 46 6			10.89	5	Observations very difficult
7 50 43			10.82	5	
18 7 37 59	288.21	6			Faint and difficult
7 45 55			13.00	4	
7 50 37			12.99	4	
19 7 38 18	245.79	5			
7 44 29			16.08	4	
7 47 40			15.82	5	

On February 13, the definition was so good that the apparent diameter of *Neptune* was measured = 2″.36, which is in close accord with my measures made with the 36-inch at the Lick Observatory.

Yerkes Observatory, Williams Bay, Wis., 1899 *May* 3.

MICROMETRICAL MEASURES OF THE COMPANIONS OF *PROCYON*,

MADE WITH THE 40-INCH REFRACTOR OF THE YERKES OBSERVATORY,

By E. E. BARNARD.

The severe weather of the past winter has made it difficult to get any measures of the close companion of *Procyon*. It was almost impossible to get any complete sets of measures — the good seeing not lasting long enough at a time. Five sets of position-angles and three of distances however were obtained. The companion is an excellent test for good seeing, for unless the seeing is not the best no trace of it can be seen. With good seeing it is an easy enough object.

Close Companion.

	P.A.	Distance
	°	″
1898.739*	330.6 ±	. .
.900	328.1	4.91
1899.087	329.7	4.83
.303	332.4	4.98
.333	332.2	. .
1899.073	330.6	4.91

* Two settings for angle only.

Yerkes Observatory, Williams Bay, Wis., 1899 *May* 4.

At the first and last observations, the distance could not be measured. My measures last year (see *A.J.* 435) gave

1898.213 326°.0 (7 nights) 4″.83 (6 nights)

The angle seems to have increased 4° or 5° in the year's time.

The old, distant companion, was measured on five nights. The change in this companion is entirely due to the proper motion of *Procyon*.

Distant Companion.

	P.A.	Distance
	°	″
1898.900	342.3	58.47
.914	342.2	58.59
.944	342.3	58.62
.947	342.7	58.60
1899.215	343.1	58.46
1898.984	342.52	58.55

ON THE VARIABLE DM. +30°591,

By G. MÜLLER and P. KEMPF.

The star DM. +30°591, whose variability we announced in *A.J.* 434, and with regard to which we could at that time prove only that its brightness has for several years regularly diminished, has since then returned almost to its original brightness with unexpected rapidity. During the appearance 1898–99 we have obtained 31 observations of it, which give the following mean values of the brightness:

1898 Sept. 8	11 obs.	$6^{\mathrm{M}}.79$
1898 Dec. 6	10 obs.	6.53
1899 Feb. 24	10 obs.	6.37

The star has thus increased about $0^{\mathrm{M}}.42$ in 169 days, while it occupied during decrease of a similar amount not less than about 1200 days. The velocity of the increase is thus more than seven times that of decrease.

Representing the mean values given here and in *A.J.* 434 by a curve, the time of minimum is 1898 Feb. 4. This determination however is subject to considerable uncertainty since observations are unfortunately wanting directly at the inflection-point, so that a certain arbitrariness in the drawing of the curve is not to be avoided. According as we draw the turns of the curve more or less sharply the epoch of minimum varies between the beginning of January and the end of April. Retaining the above adopted date, and on the other hand assuming the times when the star begins to vary from its maximum brightness corresponding to the points attained, according to the curve, on the dates 1892 Feb. 21 and 1899 Oct. 12, we have the following relations. The duration of the whole variation amounts to $7\frac{2}{3}$ years, of which the decrease occupies 6 years and the increase only $1\frac{2}{3}$ years. The amplitude amounts to $0^{\mathrm{M}}.6$. The duration of maximum brightness cannot at present be assigned. Our measures show a constant brightness from the beginning of 1888 to 1891; and if two measures in 1886 (Annals of H. C. O. vol. 24) by Pickering be included, which make the star $0^{\mathrm{M}}.1$ brighter than DM. +30°582, whose magnitude is 6.46, it may be concluded that the star remained constant for 6 years, from 1886 to 1891.

The star has no analogue among previously known variables. The course of the light-curve is indeed similar to that of δ *Cephei* and others of the same type, but distinguishes itself from these not only by the abnormal duration of its oscillations but especially by its protracted continuance at maximum brightness. A final judgement as to the character of the variability will first be attained when a repetition of the fluctuations observed by us occurs. Unfortunately this will require a long period of waiting.

Potsdam, Astrophysikalischer Observatorium, 1899 *May* 3.

OBSERVATIONS OF COMET *c* 1899 = 1873 II,

MADE WITH THE 36-INCH REFRACTOR OF THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA.

By C. D. PERRINE.

1899 Mt. Hamilton M.T.	✱	No. Comp.	☄ – ✱ $\Delta\alpha$	☄ – ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			m s	″	h m s	° ′ ″		
May 6 13 40 29	1	d10, 8	–0 0.61	+1 56.2	18 52 57.78	–4 32 19.1	n9.410	0.763
7 14 53 14	3	d10, 8	–0 3.14	+2 18.1	18 51 44.33	–4 28 10.6	n9.064	0.768

Mean Places for 1899.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	18 52 55.50	+2.89	–4 34 13.6	–1.7	Micrometer-comparison with ✱2
2	18 55 48.72	+2.88	–4 34 52.0	–1.5	Radcliffe 35022
3	18 54 41.57	+2.90	–4 30 27.3	–1.4	Schjellerup 7077

Following are the remarkably small deviations of these two positions from Schulhof's ephemeris in *A.N.* 3554.

Obs. – Comp.	May 6	$\Delta\alpha = -5^{s}.61$	$\Delta\delta = -12''.9$
	7	–5.58	–13.5

The comet is not above 10″ in diameter, round, and $15\frac{1}{2}$–16 magnitude. It is brighter at the center, and at times a very faint stellar point was suspected.

It is of interest to note the apparent rapid decrease in brightness of this comet at its last three apparitions. Its theoretical brightness at the last observation in 1878 by Tempel, as computed by the formula $\frac{1}{r^2 r'^2}$ was 0.113; in 1894, at the time of its discovery by Finlay, its theoretical brightness was 0.190, while its observed brightness was not greater than 11^{M}. At its present apparition the theoretical brightness should be 0.475, observed brightness only $15\frac{1}{2}^{\mathrm{M}}$–$16^{\mathrm{M}}$.

Mt. Hamilton, Cal., 1899 *May* 8.

NEW ELEMENTS AND AN EPHEMERIS OF PLANET (367),

BY S. C. REESE.

I have computed the perturbations due to *Jupiter* of asteroid (367) *AA*, and have deduced a new set of elements and an ephemeris. In this work I used as a basis the elements of (367) computed by BERBERICH (*Berl. Jahrb.* 1900). They are as follows:

Epoch and Osculation 1897 Aug. 27.0, Berl. M.T.

$$\left.\begin{aligned} M &= 198^\circ\ 47'\ 10''.7 \\ \omega &= 53\ 14\ 45.7 \\ \Omega &= 83\ 2\ 9.0 \\ i &= 2\ 56\ 43.5 \\ q &= 5\ 26\ 45.6 \\ \mu &= 1073''.7826 \\ \log a &= 0.3460601 \end{aligned}\right\}\ 1900.0$$

The perturbations were then computed by ENCKE's method.

As an additional check formula I deduced and applied the following:

$$40\frac{d\delta\omega}{dt} = -\frac{p}{\rho}\cos vR_0 + \frac{1}{\rho}\left(\frac{p}{r}+1\right) r\sin vS_0 + (-\cot i)\ r\sin u W_0$$

which is derived by an obvious transformation from the combination of

$$40\frac{d\delta\pi}{dt} = -\frac{p}{\rho}\cos vR_0 + \frac{1}{\rho}\left(\frac{p}{r}+1\right) r\sin vS_0 + (\tan\tfrac{1}{2}i)\ r\sin u W_0$$

and

$$40\frac{d\delta\Omega}{dt} = \frac{1}{\sin i}\ r\sin u W_0$$

In the application of the formulas 40-day intervals were used, and larger intervals might have been employed without sacrifice of accuracy.

Princeton, N.J.

The variations of the elements for 1898 Dec. 20.0 B.M.T., are as follows:

$$\begin{aligned} \delta M &= +217''.8607 & \delta i &= -0''.0178 \\ \delta\omega &= -209.0368 & \delta q &= -6.3655 \\ \delta\Omega &= +\ 17.6462 & \delta\mu &= +0.8904 \end{aligned}$$

which give

Epoch and Osculation 1898 Dec. 20.0 B.M.T.

$$\left.\begin{aligned} M &= 342^\circ\ 1'\ 4''.13 \\ \omega &= 53\ 11\ 16.67 \\ \Omega &= 83\ 2\ 26.65 \\ i &= 2\ 56\ 43.45 \\ q &= 5\ 26\ 39.22 \\ \mu &= 1074''.6730 \\ \log a &= 0.3458202 \end{aligned}\right\}\ \text{Mean Equin. } 1900.0$$

CONSTANTS.

$$\begin{aligned} x &= r\ .\ 9.99942 \sin(226^\circ\ 13'.2 + v) \\ y &= r\ .\ 9.96163 \sin(137\ 30.6 + v) \\ z &= r\ .\ 9.60895 \sin(129\ 37.6 + v) \end{aligned}$$

Date	α	δ
	h m s	° ′
May 20.75	9 32 4.6	+17 52.1
21.75	9 33 47.1	17 42.8
22.75	9 35 30.0	17 33.5
23.75	9 37 12.8	17 24.2
24.75	9 38 53.1	17 15.1
25.75	9 40 33.4	17 5.9
26.75	9 42 13.7	16 56.7
27.75	9 43 54.0	16 47.5
28.75	9 45 34.6	16 40.6
29.75	9 47 15.2	16 33.7
30.75	9 48 55.8	16 26.8
31.75	9 50 36.4	+16 19.9

ABERRATION-CONSTANT FROM RIGHT-ASCENSION OBSERVATIONS,

BY S. C. CHANDLER.

The essential conclusion from the discussions in *A.J.* 444 and *A.N.* 3562, as regards the constant of aberration given by the observations of *Polaris* with the Pulkowa Transit, is the same in both; namely, that there is plausible reason to assume the existence of systematic discordance in the observed right-ascensions, from whatever cause arising, dependent on the time of culmination; in virtue of which we get the values given under A below—in the first column if we use the whole material in two groups (January–June) and (July–December); in the second column if we limit ourselves to the middle portions of those intervals. In either case there appears to be a material excess over the values in column B, obtained without taking account of such possible systematic error.

	A		B
	A.J. 444	*A.N.* 3562	
	″	″	″
Schweizer	20.573	20.549	20.498
Wagner, Eye-and-Ear	20.506	20.494	20.478
Wagner, Chron.	20.529	20.510	20.489
Mean	20.536	20.518	20.488

This is as far as reasonable inference can at present go. The actual demonstration of the existence of such a systematic error, and especially its nature, can be accomplished only by a new series of observations undertaken for the purpose. Such an investigation is of course highly desirable.

OBSERVATIONS OF MINOR PLANETS,

MADE AT THE OBSERVATORY OF VASSAR COLLEGE WITH THE 12-INCH REFRACTOR.

By MARY W. WHITNEY and ALICE EVERETT.

1898-99 Greenwich M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's Apparent α	Planet's Apparent δ	log pΔ for α	log pΔ for δ	Obs.
				(219) *Thusnelda.*					
Oct. 20 16 16 19	1	10	+0 49.22	−2 39.8	0 4 1.95	+ 2 50 15.4	9.154	0.743	AE
22 17 0 49	2	3	+4 35.20	−2 48.9	0 4 3.47	+ 2 19 51.1	9.368	0.750	AE
23 13 59 31	3	12	−1 12.41	+6 42.6	0 3 56.67	+ 2 9 39.2	n8.980	0.749	AE
				(266) *Aline.*					
Dec. 8 13 42 54	4	5	−1 4.93	−0 53.9	4 43 47.44	+15 32 31.4	n9.480	0.634	W
9 15 43 4	5	5	−0 22.74	+1 13.5	4 42 47.72	+15 24 49.7	n9.897	0.592	W
13 16 33 25	6	5	−2 11.77	−0 48.4	4 39 11.90	+14 57 23.5	8.778	0.598	W
				(46) *Hestia.*					
Dec. 14 16 10 35	7	6	+0 23.42	−1 22.6	6 16 11.21	+19 38 19.4	n9.234	0.537	W
15 14 1 56	7	5	−0 34.18	−1 14.6	6 15 13.63	+19 38 27.4	n9.570	0.619	W
16 13 4 29	7	5	−1 35.07	−1 8.1	6 14 12.76	+19 38 33.9	n9.630	0.662	W
				(11) *Parthenope.*					
1899 Jan. 30 16 0 45	8	4	−0 13.56	+2 13.8	8 50 13.82	+18 23 25.1	n9.110	0.550	W
Feb. 1 15 43 51	9	1	0 0.00	−2 15.7	8 48 15.31	+18 34 35.3	n9.155	0.519	W
9 15 36 43	10	3	+0 51.55	+2 52.1	8 40 29.69	+19 17 13.1	n8.902	0.528	W
10 14 4 53	11	5	−0 26.34	−3 0.2	8 39 37.54	+19 21 50.2	n9.390	0.563	W
				(402) ———					
Mar. 12 15 56 29	12	10	+0 16.28	−8 45.4	10 43 51.94	+20 10 39.1	n8.626	0.508	W
14 16 10 56	12	6	−1 10.82	+6 55.7	10 42 24.83	+20 26 20.3	7.812	0.502	W
16 16 22 12	13	6	−3 7.64	+8 38.6	10 41 2.84	+20 40 51.3	8.687	0.498	W
				(6) *Hebe.*					
Apr. 3 15 57 40	14	4	+3 14.05	+2 30.2	12 25 53.74	+14 51 1.8	n8.839	0.600	W
4 15 5 30	14	4	+2 25.69	+8 58.0	12 25 5.39	+14 57 29.6	n9.206	0.608	W
5 14 17 44	15	4	−0 26.41	−8 22.8	12 24 17.76	+15 3 50.0	n9.376	0.622	W

Mean Places for 1898.0 and 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	0 3 8.19	+4.54	+ 2 52 25.2	+30.0	Boss, Albany A.G. Catal. 9
2	23 59 23.74	+4.53	+ 2 22 10.2	+30.0	Boss, Albany A.G. Catal. 8240
3	0 5 4.53	+4.55	+ 2 2 26.6	+30.0	Bonn VI, +1°.9
4	4 44 46.67	+5.70	+15 33 13.6	+11.7	Auwers, Berlin A.G. Catal. 1324
5	4 43 4.76	+5.70	+15 23 24.4	+11.8	Auwers, Berlin A.G. Catal. 1314
6	4 41 17.93	+5.74	+14 58 0.1	+11.8	Bonn VI, +14°754
7	6 15 41.79	+6.00	+19 39 43.1	− 1.1	Auwers, Berlin A.G. Catal. 2093
8	8 50 24.46	+2.92	+18 21 22.0	−10.7	Bonn VI, +18°2084
9	8 48 12.37	+2.94	+18 37 1.6	−10.6	Auwers, Berlin A.G. Catal. 3572
10	8 39 35.11	+3.03	+19 14 31.2	−10.2	Auwers, Berlin A.G. Catal. 3507
11	8 40 0.84	+3.04	+19 25 0.6	−10.2	Auwers, Berlin A.G. Catal. 3512
12	10 43 32.54	+3.12	+20 19 40.7	−16.2	Becker, Berlin A.G. Catal. 4108
13	10 44 7.37	+3.11	+20 32 28.6	−15.9	Becker, Berlin A.G. Catal. 4111
14	12 22 36.59	+3.10	+14 48 50.3	−18.7	Auwers, Berlin A.G. Catal. 4681

Parthenope and *Hebe* were observed with the filar micrometer. The remainder with the square-bar micrometer.

ELEMENTS OF COMET a 1899 (SWIFT),

BY C. J. MERFIELD.

The appended elements of this comet have been deduced from three positions for the dates 1899 March 7, 1899 March 13 and 1899 March 19.

These positions were obtained by comparing some twenty observations with an ephemeris computed from preliminary elements.

The observations were taken by Mr. J. TEBBUTT of Windsor, and kindly communicated to the writer.

This comet will be well placed for observation early in May, and its brightness will be about twice that at the time of discovery. On the date 1899 May 27 it will be near to the earth, and will be seen before sunrise by both northern and southern observatories.

Sidney, New South Wales, 1899 *April* 8.

ELEMENTS.

$$T = \text{April } 12.96406 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 9^\circ\ 2'\ 32''.8 \\ \Omega &= 25\ \ 7\ 35.9 \\ i &= 146\ 16\ \ 1.0 \end{aligned}\right\} 1899$$

$$\log q = 9.5118112$$

RESIDUAL OF MIDDLE PLACE.

$$\text{O}-\text{C}: \quad \cos\beta'\,\Delta\lambda' = -4''.9 \quad . \quad \Delta\beta' = +2''.3.$$

EQUATIONS FOR CO-ORDINATES.

$$\begin{aligned} x &= [9.9875774]\, r \sin (v + \ \ 77^\circ\ 11'\ \ 5''.3) \\ y &= [9.9962838]\, r \sin (v + 165\ 54\ 28.7) \\ z &= [9.4303811]\, r \sin (v + \ \ 47\ 53\ 42.0) \end{aligned}$$

OBSERVATIONS OF COMET a 1899 (SWIFT).

BY WILLIAM J. HUSSEY.

I have this morning obtained the following observation of this comet. It is much brighter than at the time of the March observations, before perihelion passage. It now has a considerable tail.

Mt. Hamilton M.T.	*	No. Comp.	☄ – * $\Delta\alpha$	☄ – * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
1899 May 1 15h 46m 59s	6	8 , 8	+0m 4s.52	+4' 51''.7	0h 6m 53s.41	+22° 59' 28''.6	n9.703	0.666

Mean Place for 1899.0 of Comparison-Star.

*	α	Red. to app. place	δ	Red. to app. place	Authority
6	0h 6m 47s.87	+1s.02	+22° 54' 34''.4	+2''.5	Becker, Berlin A.G. Catal. 26

PERIOD OF 2776 *W PUPPIS*,

BY ALEX. W. ROBERTS.

This star has been observed at Lovedale through several maxima and minima.

The elements, taking the first maximum of 1900 as the epoch, are,

Epoch,	1900 February 22
Period,	120 days
Minimum to maximum,	62 days
Limits,	8M.0 to 11M.0

Lovedale, South Africa, 1899 *March* 24.

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OBSERVATIONS OF *EROS*,

MADE AT THE CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, COLORADO,

By HERBERT A. HOWE.

The following observations were made with the Bruce micrometer on the 20-inch equatorial, the magnifying power being 200. The right-ascension observations are chronographic; three declination bisections were usually made during the minute occupied by the drifting of one object through the field. For the computation of the logarithms of the parallax-factors the writer is indebted to Miss AGNES McNAIR. Prof. C. J. LING, of the Denver Manual Training High School, computed the reductions to apparent place. Prof. W. C. BORST, of the same school, assisted in the computation of the mean places. Prof. A. S. FLINT, of the Washburn Observatory, kindly furnished some star places from catalogues.

1898 University Park M.T.	*	No. Comp.	Planet – * $\Delta\alpha$	Planet – * $\Delta\delta$	Planet's apparent α	Planet's apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Sept. 12 10 0 5	1	20 , 6	− 7 28.57	+ 4 16.4	20 42 38.40	− 6 20 49.9	8.960	0.798
12 10 23 23	2	20 , 6	11 35.26	− 0 48.5	20 42 37.50	6 20 52.1	9.134	0.797
12 10 50 24	3	20 , 6	5 36.58	+16 21.1	20 42 36.31	6 20 50.7	9.270	0.795
13 8 49 27	4	20 , 6	10 55.44	12 45.6	20 41 50.12	6 21 1.5	n8.595	0.800
13 9 19 14	5	20 , 6	12 5.20	+17 14.9	20 41 49.10	6 21 1.5	8.300	0.800
13 9 47 40	6	20 , 6	6 8.72	−15 59.4	20 41 48.07	6 21 2.0	8.882	0.799
14 8 32 36	7	20 , 6	6 13.18	3 25.1	20 41 3.12	6 21 12.3	n8.802	0.799
14 8 51 45	8	20 , 6	5 46.76	28 9.4	20 41 2.74	6 21 12.9	n8.405	0.800
14 9 13 9	9	20 , 6	5 39.66	2 34.6	20 41 1.75	6 21 11.5	8.236	0.800
16 9 10 28	10	20 , 6	6 29.02	21 14.1	20 39 36.38	6 21 22.7	8.483	0.800
16 9 30 15	11	20 , 6	5 40.81	6 12.0	20 39 35.81	6 21 24.7	8.842	0.799
16 9 48 51	12	20 , 6	3 47.64	− 2 56.3	20 39 35.20	6 21 24.4	9.025	0.798
17 8 46 37	13	20 , 6	3 50.82	+ 2 7.2	20 38 59.17	6 21 27.4	n7.905	0.800
17 9 1 29	14	20 , 6	2 20.89	− 0 33.9	20 38 58.91	6 21 25.9	8.334	0.800
17 9 16 22	15	20 , 6	1 40.86	+18 6.0	20 38 58.57	6 21 27.1	8.708	0.800
19 9 43 38	16	20 , 6	− 2 3.12	+ 9 56.9	20 37 52.07	6 21 22.6	9.086	0.798
19 9 59 7	17	20 , 6	+ 1 47.88	− 0 2.9	20 37 51.69	6 21 23.7	9.180	0.797
19 10 15 14	18	20 , 6	+ 3 1.26	9 18.0	20 37 51.57	6 21 23.1	9.258	0.796
22 9 25 5	19	20 , 6	− 1 54.84	1 54.7	20 36 38.39	6 20 52.6	9.046	0.798
22 9 37 17	20	20 , 6	1 58.74	23 44.6	20 36 38.26	6 20 54.8	9.129	0.797
22 9 50 3	21	20 , 6	2 24.00	−10 42.9	20 36 38.01	6 20 52.6	9.201	0.796
23 8 38 58	22	20 , 6	1 42.55	+11 32.9	20 36 20.97	6 20 35.6	8.462	0.800
23 8 52 31	23	20 , 6	− 1 17.19	23 3.1	20 36 20.32	6 20 34.9	8.746	0.799
23 9 22 34	24	20 , 6	+ 2 23.30	+12 8.8	20 36 19.98	6 20 34.9	9.059	0.798
26 10 11 52	25	20 , 5	10 23.32	− 6 14.6	20 35 43.70	6 19 15.7	9.358	0.792
26 10 39 50	26	19 , 6	10 24.90	9 29.0	20 35 43.25	6 19 15.1	9.438	0.789
26 11 9 7	27	19 , 6	10 25.52	15 7.8	20 35 43.35	6 19 14.3	9.503	0.785
29 9 17 57	26	20 , 6	10 16.57	− 7 34.2	20 35 34.87	6 17 20.4	9.182	0.796
Oct. 3 8 13 6	28	20 , 6	7 59.48	+20 6.9	20 36 3.28	6 13 36.3	8.750	0.798
3 8 40 28	29	20 , 6	6 43.43	23 8.1	20 36 3.45	6 13 35.7	9.040	0.797
3 9 8 30	30	20 , 6	6 0.96	24 34.9	20 36 3.59	6 13 33.7	9.212	0.795
4 7 49 3	29	15 , 5	6 57.06	24 15.5	20 36 17.07	6 12 28.2	8.197	0.799
4 8 17 39	30	20 , 6	+ 6 14.72	+25 42.4	20 36 17.33	− 6 12 26.2	8.860	0.798

1898 University Park M.T.		✱	No. Comp.	Planet — ✱ $\Delta\alpha$	Planet — ✱ $\Delta\delta$	Planet's apparent α	Planet's apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Oct. 4	8 35 6	15	20 , 6	− 4 21.75	+27 7.8	20 36 17.47	− 6 12 25.2	9.027	0.797
5	9 10 47	28	20 , 6	+ 8 30.95	22 33.4	20 36 34.73	6 11 9.7	9.257	0.794
5	9 26 31	24	20 , 6	+ 2 38.37	21 35.0	20 36 34.88	6 11 8.8	9.320	0.793
5	9 37 7	22	20 , 6	− 1 28.33	+23 59.2	20 36 35.02	6 11 9.4	9.357	0.792
6	7 59 3	31	20 , 6	+10 17.24	−13 18.9	20 36 53.26	6 9 52.4	8.700	0.798
6	8 20 40	32	20 , 6	3 12.54	+15 50.8	20 36 53.27	6 9 52.6	8.966	0.797
6	8 36 26	33	20 , 6	3 4.71	+20 48.8	20 36 53.91	6 9 51.7	9.090	0.796
7	7 53 30	31	20 , 6	10 39.28	−11 52.8	20 37 15.29	6 8 26.3	8.663	0.798
7	8 18 40	34	12 , 4	12 1.63	−24 51.0	20 37 15.67	6 8 25.1	8.980	0.797
10	7 54 1	35	20 , 5	10 40.78	+15 31.5	20 38 37.21	6 3 33.5	8.830	0.797
10	8 22 53	36	20 , 6	11 4.71	+13 4.8	20 38 37.77	6 3 30.7	9.093	0.796
11	7 28 21	37	20 , 6	10 52.52	−19 56.6	20 39 9.22	6 1 46.1	8.374	0.797
11	8 2 35	38	20 , 6	9 57.53	+ 9 35.6	20 39 9.70	6 1 41.6	8.960	0.796
13	7 30 23	38	20 , 6	11 8.70	13 33.7	20 40 20.82	5 57 43.6	8.612	0.797
13	7 49 8	39	20 , 6	3 43.84	+16 15.0	20 40 21.16	5 57 43.1	8.891	0.796
14	7 17 5	40	20 , 6	14 15.08	−20 35.4	20 41 0.14	5 55 36.5	8.323	0.797
14	7 50 56	41	20 , 6	13 24.05	−15 27.9	20 41 0.88	5 55 32.0	8.943	0.796
17	7 20 41	42	20 , 6	13 10.11	+ 3 57.8	20 43 12.38	5 48 19.3	8.674	0.795
17	7 58 58	43	20 , 6	15 41.00	−17 31.5	20 43 13.61	5 48 18.9	9.086	0.794
19	7 31 7	44	20 , 6	13 48.12	+ 0 28.7	20 44 52.09	5 42 59.3	8.903	0.794
19	7 58 34	45	20 , 6	8 54.24	− 9 6.7	20 44 53.31	5 42 54.5	9.124	0.793
21	6 56 49	46	20 , 6	9 28.50	+ 2 14.2	20 46 38.58	5 37 6.3	8.385	0.794
21	7 21 13	47	20 , 6	8 40.42	− 5 32.4	20 46 39.74	5 37 6.1	8.860	0.794
21	7 52 16	48	20 , 6	12 54.09	−20 2.4	20 46 40.78	5 37 2.7	9.122	0.792
24	7 37 4	49	20 , 6	1 35.84	+ 5 6.7	20 49 36.88	5 27 16.9	9.080	0.791
24	7 54 10	50	20 , 6	4 36.16	2 10.9	20 49 37.61	5 27 17.4	9.194	0.790
25	7 10 21	51	20 , 6	1 23.40	26 56.9	20 50 38.93	5 23 51.3	8.870	0.792
25	7 21 13	52	14 , 5	+ 0 56.12	27 54.9	20 50 39.53	5 23 50.8	8.979	0.792
25	7 44 35	53	30 , 9	− 4 32.61	28 25.5	20 50 40.44	5 23 44.8	9.146	0.790
25	8 24 9	54	20 , 6	+ 8 46.92	3 23.8	20 50 41.94	5 23 41.1	9.327	0.788
27	6 43 15	55	20 , 6	− 2 32.42	28 28.1	20 52 48.83	5 16 32.0	8.504	0.792
27	7 11 35	56	20 , 6	+10 25.07	+ 7 16.7	20 52 50.13	5 16 28.1	8.943	0.791
27	7 34 36	57	20 , 6	+ 6 21.05	− 6 2.6	20 52 51.01	5 16 25.8	9.120	0.790
27	7 47 11	58	20 , 6	− 6 56.38	+18 1.1	20 52 51.39	5 16 24.7	9.192	0.789
27	8 8 0	59	20 , 6	− 6 57.43	+14 10.9	20 52 52.57	5 16 21.5	9.287	0.787
29	6 45 44	60	20 , 6	+ 8 7.04	− 3 50.3	20 55 7.08	5 8 40.6	8.679	0.790
29	7 4 4	61	20 , 6	3 46.66	+12 0.3	20 55 7.41	5 8 39.8	8.924	0.790
29	7 17 52	62	20 , 6	4 6.96	9 14.2	20 55 8.76	5 8 38.1	9.044	0.789
31	6 41 34	63	20 , 6	+ 2 16.94	6 50.2	20 57 32.18	5 0 18.0	8.702	0.789
31	6 49 26	64	20 , 6	− 1 54.28	13 7.2	20 57 33.19	5 0 8.1	8.818	0.789
31	7 3 14	65	20 , 6	− 8 23.40	11 33.8	20 57 33.28	5 0 15.8	8.968	0.789
Nov. 1	6 40 57	63	20 , 6	+ 3 32.00	11 14.2	20 58 47.23	4 55 54.0	8.736	0.789
1	6 54 8	66	20 , 6	+ 2 14.00	7 45.8	20 58 46.80	4 55 52.3	8.904	0.788
1	7 4 39	67	20 , 6	− 3 36.42	6 22.0	20 58 48.27	4 55 51.9	9.003	0.788
2	6 45 55	68	20 , 6	+11 17.92	4 3.9	21 0 4.14	4 51 19.8	8.841	0.788
2	7 7 36	69	20 , 6	−12 48.32	5 11.2	21 0 5.24	4 51 20.9	9.048	0.787
2	7 36 12	70	20 , 6	− 2 18.48	+ 0 16.7	21 0 6.97	4 51 10.5	9.219	0.786
3	6 55 27	71	20 , 6	+ 1 8.75	− 0 54.6	21 1 23.37	4 46 41.0	8.969	0.787
3	7 4 22	72	20 , 6	− 2 4.70	+ 3 22.2	21 1 23.74	4 46 37.1	9.043	0.787
4	6 42 12	73	14 , 5	+ 6 19.20	−10 21.9	21 2 42.25	4 41 57.1	8.860	0.787
4	6 54 42	74	18 , 6	− 4 35.53	+ 0 38.7	21 2 43.11	4 41 55.8	8.986	0.786
5	7 1 44	75	15 , 5	12 17.61	17 53.0	21 4 4.92	4 36 57.3	9.062	0.785
5	7 12 43	76	15 , 5	12 42.26	15 22.7	21 4 5.87	4 36 57.7	9.134	0.785
14	6 51 40	77	20 , 6	2 37.44	+12 44.6	21 17 23.92	3 46 32.0	9.140	0.778
14	7 34 37	78	20 , 6	− 6 41.16	− 7 6.6	21 17 26.45	3 46 19.4	9.335	0.776
14	7 56 48	79	20 , 6	+ 0 56.76	− 8 39.4	21 17 28.22	3 46 17.3	9.404	0.774
15	6 35 36	80	20 , 8	− 0 37.68	+ 9 28.2	21 18 58.50	3 40 17.6	9.049	0.778
15	6 48 57	81	20 , 6	+ 1 47.72	− 6 43.5	21 18 59.71	3 40 13.7	9.138	0.778
15	7 2 6	82	20 , 6	− 8 51.08	1 56.5	21 19 0.16	3 40 15.2	9.209	0.777
16	6 52 36	83	20 , 6	+ 4 46.54	− 4 33.0	21 20 36.82	− 3 33 45.1	9.172	0.776

1898–99	Univ. Park M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's apparent α	Planet's apparent δ	log pΔ for α	log pΔ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Nov. 16	7 6 45	84	20 , 6	+ 4 41.52	− 5 52.9	21 20 37.33	− 3 33 51.1	9.212	0.776
16	7 17 7	85	20 , 6	− 6 39.72	− 3 52.5	21 20 38.56	3 33 39.5	9.287	0.775
18	6 53 32	86	20 , 6	+ 6 43.76	+ 8 38.6	21 23 54.77	3 20 30.3	9.201	0.774
18	7 7 33	87	20 , 6	+ 2 40.62	4 53.2	21 23 55.82	3 20 20.7	9.266	0.774
18	7 25 26	88	20 , 6	− 3 9.34	0 19.8	21 23 56.82	3 20 21.9	9.335	0.773
Dec. 5	6 55 12	89	20 , 6	+ 3 0.25	10 35.6	21 54 57.85	1 5 2.1	9.354	0.756
5	7 5 18	90	20 , 6	− 2 22.84	19 13.3	21 54 58.66	1 5 2.8	9.385	0.756
5	7 18 48	91	19 , 6	− 4 36.45	18 41.2	21 54 59.73	1 4 52.8	9.423	0.755
6	6 46 27	92	19 , 6	+ 5 41.52	13 32.0	21 56 55.89	0 55 56.2	9.330	0.755
6	7 5 30	93	20 , 6	4 26.91	10 34.1	21 56 57.65	0 55 46.4	9.392	0.754
6	7 17 1	94	20 , 6	1 37.45	7 57.5	21 56 58.31	0 55 43.7	9.424	0.754
9	6 52 37	95	20 , 6	+ 2 22.06	+20 58.0	22 2 58.21	0 27 34.5	9.370	0.751
9	7 4 43	96	20 , 4	− 6 12.53	− 0 25.1	22 2 59.19	0 27 26.7	9.406	0.751
9	7 38 6	97	20 , 6	+ 9 14.77	− 4 5.6	22 3 1.90	0 27 11.8	9.486	0.750
10	6 35 23	98	20 , 6	1 28.93	+ 7 57.5	22 4 59.09	0 17 54.5	9.318	0.750
10	6 55 59	99	20 , 6	8 22.59	− 8 51.1	22 5 0.84	0 17 48.7	9.386	0.750
10	7 12 31	100	10 , 3	6 45.55	− 4 10.1	22 5 2.49	− 0 17 38.6	9.432	0.750
12	6 45 26	101	20 , 6	5 37.48	+11 15.6	22 9 7.76	+ 0 2 0.6	9.365	0.747
12	6 59 6	102	20 , 6	3 3.44	4 47.7	22 9 9.10	0 2 6.9	9.406	0.747
12	7 14 16	103	20 , 6	+ 1 0.35	17 33.8	22 9 10.30	0 2 12.3	9.445	0.747
13	6 44 4	104	20 , 7	− 0 22.99	10 41.2	22 11 12.80	0 12 7.7	9.367	0.746
13	7 8 5	105	20 , 6	+ 9 18.60	7 36.8	22 11 14.91	0 12 16.9	9.435	0.746
13	7 30 6	106	20 , 6	7 2.81	+ 0 13.1	22 11 16.79	0 12 25.1	9.485	0.746
14	6 35 24	107	20 , 6	+ 4 37.60	− 0 27.3	22 13 18.10	0 22 19.7	9.344	0.744
14	6 45 5	108	20 , 6	− 3 12.67	+14 9.3	22 13 18.99	0 22 22.6	9.376	0.744
14	6 58 41	109	20 , 6	− 4 57.90	16 28.6	22 13 20.37	0 22 29.3	9.415	0.744
15	6 37 48	110	20 . 6	+ 4 56.10	4 20.2	22 15 25.11	0 32 43.5	9.358	0.743
15	6 49 0	111	20 , 6	+ 2 4.55	10 42.5	22 15 26.44	0 32 46.9	9.393	0.743
15	6 57 22	112	19 , 6	− 2 8.39	14 0.4	22 15 27.00	0 32 53.9	9.416	0.743
16	6 34 56	113	20 , 6	+ 5 39.04	4 58.0	22 17 33.02	0 43 10.3	9.355	0.742
16	6 46 45	114	20 , 6	+ 1 37.76	11 26.4	22 17 33.64	0 43 22.5	9.392	0.742
16	6 56 7	115	20 , 6	− 0 54.96	14 57.7	22 17 34.74	0 43 21.9	9.418	0.742
17	6 35 6	116	20 . 6	4 2.26	4 56.9	22 19 41.87	0 53 48.1	9.361	0.740
17	6 49 0	117	20 , 6	4 9.40	6 25.0	22 19 43.00	0 53 57.2	9.403	0.740
17	7 2 30	118	20 , 6	4 45.96	7 13.0	22 19 44.36	0 54 3.9	9.439	0.741
17	7 17 29	119	19 , 8	− 0 21.90	2 9.1	22 19 45.67	0 54 8.1	9.474	0.741
21	7 2 58	120	20 , 6	+ 3 14.89	6 9.4	22 28 27.43	1 37 47.9	9.457	0.735
21	7 21 15	121	20 , 6	6 28.58	4 9.0	22 28 29.32	1 37 56.2	9.494	0.736
21	7 38 40	122	13 , 6	7 14.68	+10 38.0	22 28 30.95	1 38 4.0	9.528	0.737
23	6 29 44	123	20 , 6	2 29.56	− 2 21.8	22 32 51.29	2 0 8.1	9.378	0.731
23	7 7 9	124	20 , 6	+ 5 10.52	3 42.8	22 32 54.67	2 0 27.3	9.474	0.733
23	7 18 34	125	20 , 6	− 6 53.62	3 3.6	22 32 55.64	2 0 31.6	9.498	0.734
26	6 26 42	126	19 , 6	+ 4 16.11	1 37.3	22 39 36.98	2 34 52.2	9.384	0.726
26	6 41 0	127	17 , 6	4 56.29	− 8 5.7	22 39 38.34	2 34 58.3	9.424	0.727
26	6 54 8	128	20 , 6	+ 2 15.13	+12 34.8	22 39 39.58	2 35 6.3	9.456	0.728
26	7 3 23	129	18 , 6	− 2 41.31	+12 45.3	22 39 40.22	2 35 11.9	9.477	0.729
27	6 52 45	130	20 , 6	+ 1 53.75	− 3 40.8	22 41 56.37	2 46 55.8	9.457	0.727
27	7 2 0	131	20 , 6	− 2 23.12	+ 4 24.1	22 41 57.07	2 47 0.7	9.478	0.727
27	7 29 4	132	20 , 6	+ 8 37.52	− 1 54.9	22 41 59.86	2 47 12.2	9.529	0.729
28	6 30 37	133	20 , 6	3 11.59	− 7 25.1	22 44 12.05	2 58 41.4	9.405	0.723
28	6 40 14	134	20 , 8	+ 0 23.94	+ 0 3.4	22 44 13.11	2 58 45.5	9.431	0.724
28	6 52 20	135	20 , 6	− 3 11.08	− 2 14.0	22 44 14.11	2 58 51.8	9.460	0.725
31	7 14 38	136	20 , 6	+ 2 46.15	− 6 28.7	22 51 14.30	3 35 26.9	9.516	0.723
31	7 26 34	137	20 , 6	+ 1 15.58	+ 1 2.1	22 51 15.44	3 35 32.9	9.536	0.724
31	7 37 17	138	19 , 6	− 2 16.33	+ 7 27.5	22 51 16.45	3 35 39.5	9.553	0.726
1899 Jan. 2	6 58 22	139	20 , 6	+ 1 13.64	+10 52.9	22 55 55.23	4 0 9.3	9.491	0.719
2	7 7 27	140	20 , 8	− 0 35.18	+ 4 50.6	22 55 56.20	4 0 15.5	9.509	0.720
2	7 18 6	141	20 , 6	− 3 52.24	− 3 6.5	22 55 57.31	4 0 18.1	9.528	0.721
3	6 56 7	142	20 , 8	+ 0 36.24	− 4 13.1	22 58 17.70	4 12 40.1	9.490	0.717
3	7 5 47	143	20 , 6	− 2 41.30	+ 4 11.4	22 58 18.41	+4 12 44.9	9.509	0.718

1899 University Park M.T.		$*$	No. Comp.	Planet — $*$ $\Delta\alpha$	Planet — $*$ $\Delta\delta$	Planet's apparent α	Planet's apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Jan. 3	7 18 3	144	20 , 6	− 5 7.33	+ 4 54.5	22 58 19.87	+ 4 12 52.7	9.530	0.720
4	6 31 51	145	20 , 6	+ 2 38.96	+ 1 12.5	23 0 38.55	4 25 7.3	9.438	0.712
4	6 39 45	146	19 , 6	− 1 0.10	− 4 19.3	23 0 39.31	4 25 10.0	9.457	0.713
4	6 48 44	147	20 , 6	− 2 15.48	+ 5 29.5	23 0 40.33	4 25 14.6	9.478	0.714
5	6 29 34	148	20 , 8	+ 0 40.28	4 34.0	23 3 2.58	4 37 50.9	9.437	0.710
5	6 48 18	149	20 , 6	− 1 49.42	+ 2 17.2	23 3 4.30	4 38 0.6	9.480	0.713
5	6 57 49	150	19 , 3	− 2 56.50	− 1 48.8	23 3 5.34	4 38 5.6	9.499	0.714
6	6 45 14	151	20 , 6	+ 1 45.93	+ 3 17.9	23 5 29.27	4 50 50.7	9.477	0.711
6	6 53 18	152	20 , 6	− 2 31.86	− 1 29.9	23 5 29.94	4 50 52.9	9.494	0.712
6	7 5 3	153	20 , 6	− 3 13.08	+ 6 18.0	23 5 31.23	4 51 1.0	9.516	0.714
7	7 0 5	154	20 , 6	+ 2 48.28	− 3 22.2	23 7 56.39	5 3 57.6	9.510	0.712
7	7 7 40	155	20 , 6	− 1 55.12	+ 6 35.2	23 7 57.15	5 3 58.7	9.524	0.713
7	7 21 2	156	20 , 6	2 0.13	7 12.5	23 7 58.46	5 4 7.0	9.546	0.715
9	6 45 42	157	20 , 6	1 32.27	+ 9 50.4	23 12 48.84	5 29 57.9	9.488	0.706
9	6 57 39	158	20 , 6	6 24.05	− 7 53.1	23 12 49.91	5 30 5.6	9.511	0.708
9	7 16 35	159	20 , 6	7 21.92	+ 0 58.9	23 12 52.00	5 30 15.4	9.544	0.712
13	6 34 23	160	19 , 6	4 19.59	− 8 36.4	23 22 45.56	6 23 15.2	9.477	0.698
13	6 50 8	161	20 , 6	8 19.84	+ 5 6.4	23 22 47.02	6 23 23.6	9.509	0.701
13	7 13 47	162	20 , 6	−10 39.28	+13 36.3	23 22 49.66	6 23 38.5	9.549	0.706
14	6 46 15	163	20 , 6	+11 5.21	− 2 59.1	23 25 18.06	6 36 53.9	9.504	0.699
14	7 2 8	164	20 , 6	− 9 30.35	15 45.3	23 25 19.71	6 37 2.1	9.533	0.702
14	7 28 24	165	19 , 6	11 25.91	− 4 19.6	23 25 22.70	6 37 18.2	9.571	0.708
17	6 47 26	166	19 , 6	2 25.14	+ 1 8.4	23 32 57.64	7 18 1.1	9.515	0.694
17	6 58 14	167	20 , 6	2 32.02	− 1 35.9	23 32 58.90	7 18 4.4	9.534	0.697
17	7 8 50	168	20 , 6	2 34.08	4 45.4	23 32 59.96	7 18 10.7	9.551	0.699
18	6 37 56	169	19 , 6	1 1.57	7 3.4	23 35 31.29	7 31 42.2	9.500	0.690
18	6 47 40	170	19 , 6	− 4 31.84	− 8 32.6	23 35 32.13	7 31 46.2	9.518	0.693
18	7 17 21	171	19 , 6	+ 9 48.60	+ 5 38.1	23 35 35.76	7 32 7.4	9.565	0.700
19	6 40 49	172	19 , 6	− 4 55.73	4 26.4	23 38 7.39	7 45 40.2	9.508	0.689
19	7 1 50	173	20 , 6	+ 4 25.38	+ 0 29.6	23 38 9.72	7 45 50.6	9.545	0.695
19	7 22 47	174	20 , 6	7 43.97	− 3 32.8	23 38 11.66	7 46 4.1	9.575	0.700
20	6 36 34	175	20 , 6	+ 1 21.08	+ 2 46.6	23 40 43.37	7 59 35.2	9.503	0.686
20	6 46 55	176	20 , 5	− 6 48.90	− 9 56.2	28 40 44.36	7 59 42.7	9.522	0.689
20	7 25 38	177	19 , 6	+10 29.56	+ 2 16.8	23 40 48.91	8 0 3.5	9.580	0.700
23	6 33 26	178	20 , 8	− 0 36.02	6 42.9	23 48 37.21	8 41 45.0	9.505	0.680
23	6 45 10	179	20 , 6	4 57.38	0 48.3	23 48 38.26	8 41 51.7	9.526	0.684
23	7 2 58	180	20 , 6	8 33.61	+18 15.2	23 48 40.73	8 42 2.6	9.555	0.689
31	6 41 24	181	20 , 6	2 45.26	− 2 30.4	0 10 20.70	10 36 22.6	9.539	0.670
Feb. 1	7 8 17	182	20 , 7	− 0 28.71	+ 7 15.2	0 13 10.36	10 51 7.7	9.581	0.679
1	7 31 11	183	20 , 6	+ 8 21.74	16 10.6	0 13 12.91	10 51 18.9	9.607	0.689
1	7 59 16	184	20 , 5	9 55.17	+14 54.5	0 13 16.03	10 51 33.1	9.632	0.701
6	7 4 1	185	20 , 8	+ 0 49.43	−18 10.5	0 27 17.84	12 3 35.0	9.584	0.670
6	7 16 8	186	20 , 6	− 1 6.34	3 16.4	0 27 18.88	12 3 43.0	9.599	0.676
6	7 40 32	187	10 , 3	+11 34.93	8 53.4	0 27 21.91	12 3 54.1	9.623	0.688
6	7 55 23	188	10 , 2	11 24.86	− 5 12.4	0 27 23.93	12 4 6.2	9.635	0.695
9	7 13 37	189	17 , 6	4 40.56	+ 4 9.6	0 35 58.73	12 47 14.7	9.601	0.671
9	7 31 29	190	20 , 6	5 19.67	+ 7 57.3	0 36 1.42	12 47 29.8	9.619	0.680
9	7 54 9	191	20 , 6	6 22.27	− 1 26.0	0 36 4.14	12 47 37.5	9.638	0.692
11	6 57 43	192	20 , 6	+ 3 39.20	− 6 40.6	0 41 48.42	13 16 5.1	9.585	0.660
11	7 11 7	193	20 , 6	− 5 22.01	+10 3.6	0 41 50.18	13 16 10.6	9.601	0.667
11	7 30 32	194	20 , 6	8 59.11	− 8 3.0	0 41 52.75	13 16 21.1	9.621	0.678
14	6 48 20	195	20 , 6	− 3 43.98	− 4 43.6	0 50 42.00	13 59 16.6	9.578	0.650
14	7 5 10	196	20 , 6	+ 2 51.70	+ 3 57.1	0 50 43.98	13 59 33.1	9.599	0.659
14	7 22 26	197	20 , 6	+ 6 21.10	4 41.2	0 50 46.46	13 59 46.1	9.618	0.670
16	6 53 20	198	20 , 6	− 3 2.04	3 46.0	0 56 44.03	14 28 3.7	9.588	0.650
16	7 8 16	199	20 , 6	3 43.59	+ 1 37.4	0 56 45.75	14 28 13.7	9.606	0.659
18	6 47 8	200	20 , 6	2 2.19	−11 45.2	1 2 48.46	14 56 34.5	9.583	0.643
18	6 57 2	201	20 , 6	2 19.58	11 17.5	1 2 49.81	14 56 39.6	9.596	0.649
18	7 10 53	202	20 , 6	9 40.19	10 13.1	1 2 51.52	14 56 47.7	9.611	0.658
23	7 2 38	203	20 , 6	− 3 47.19	− 8 53.2	1 18 21.66	+16 7 4.2	9.609	0.646

1899 University Park M.T.			*	No. Comp.	Planet — *		Planet's apparent		log $p\Delta$	
					$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
		h m s			m s	′ ″	h m s	° ′ ″		
Feb.	23	7 22 1	204	20 , 6	+ 4 24.85	— 1 20.4	1 18 24.38	+16 7 18.1	9.629	0.659
	23	7 32 49	205	20 , 6	+ 1 26.15	10 39.9	1 18 25.79	16 7 23.1	9.638	0.667
	27	6 57 26	206	20 , 6	— 2 37.00	— 2 56.2	1 31 4.67	17 1 53.8	9.609	0.636
	27	7 8 39	207	20 , 6	— 4 14.80	+ 4 51.4	1 31 6.05	17 2 2.6	9.621	0.645
	27	7 27 11	208	20 , 6	+ 3 3.96	— 5 36.1	1 31 8.62	17 2 12.0	9.638	0.659
	27	7 37 43	209	20 , 6	2 49.03	7 50.1	1 31 9.87	17 2 17.8	9.646	0.667
Mar.	1	7 3 17	210	20 , 6	3 56.37	— 4 51.8	1 37 33.68	17 28 52.4	9.618	0.628
	1	7 16 44	211	20 , 6	+ 2 29.70	+ 7 17.7	1 37 35.38	17 28 59.7	9.631	0.649
	1	7 26 24	212	19 , 6	— 5 40.76	+11 49.4	1 37 36.75	17 29 1.6	9.639	0.656
	9	7 14 22	213	20 , 6	3 6.73	— 9 28.1	2 4 11.39	19 11 29.5	9.638	0.657
	9	7 26 50	214	19 , 6	6 25.62	1 51.4	2 4 13.22	19 11 36.0	9.648	0.648
	9	7 44 46	215	19 , 6	8 3.01	1 10.8	2 4 15.70	19 11 45.7	9.660	0.664
	9	8 8 10	216	20 , 6	9 13.44	— 1 40.7	2 4 19.19	19 12 1.4	9.672	0.684
	11	7 44 29	217	20 , 8	0 28.57	+ 0 50.3	2 11 5.90	19 35 58.4	9.662	0.662
	11	7 58 52	218	29 , 9	1 23.12	+ 9 55.0	2 11 8.04	19 36 3.8	9.669	0.675
	11	8 11 42	219	20 , 6	3 45.79	— 3 35.6	2 11 9.85	19 36 9.8	9.674	0.686
	14	7 23 2	220	25 , 10	0 43.54	+ 7 25.1	2 21 26.23	20 10 46.1	9.650	0.640
	14	7 47 47	221	20 , 6	4 26.85	— 1 40.0	2 21 29.70	20 11 0.9	9.666	0.663
	15	7 19 22	222	20 , 6	— 0 1.51	4 0.8	2 24 55.54	20 22 1.1	9.648	0.636
	15	7 29 11	223	19 , 6	+ 1 15.39	1 37.9	2 24 57.08	20 22 9.7	9.655	0.645
	15	7 39 51	224	20 , 6	— 5 31.99	4 36.6	2 24 58.58	20 22 12.3	9.662	0.655
	18	7 23 21	225	19 , 6	— 3 52.39	— 2 40.7	2 35 32.71	20 54 46.5	9.653	0.636
	18	7 44 47	226	20 , 6	+ 3 50.24	+ 3 38.5	2 35 35.79	20 54 58.4	9.667	0.657
	18	7 57 52	227	20 , 6	3 44.18	— 3 50.1	2 35 37.54	20 55 5.6	9.674	0.670
	18	8 8 18	228	20 , 8	0 41.87	+ 7 43.1	2 35 39.23	20 55 8.6	9.678	0.680
	23	7 41 27	229	10 , 3	2 19.66	— 2 28.4	2 53 36.88	21 45 4.4	9.669	0.650
	28	7 32 12	230	20 , 12	0 3.94	+ 1 18.7	3 12 1.70	22 29 9.6	9.666	0.637
	28	7 49 21	231	20 , 7	0 58.78	+ 1 28.9	3 12 4.33	22 29 15.6	9.676	0.655
	28	8 4 56	232	20 , 8	+ 0 43.11	— 5 47.7	3 12 6.80	22 29 21.2	9.682	0.671
	28	8 17 32	233	19 , 6	— 4 30.18	+ 2 25.9	3 12 8.98	22 29 22.8	9.686	0.684
Apr.	3	7 42 9	234	20 , 8	0 43.41	+ 3 15.4	3 34 42.58	23 13 5.7	9.675	0.644
	3	7 53 35	235	20 , 6	2 59.35	— 6 42.2	3 34 44.53	23 13 8.8	9.681	0.656
	3	8 5 46	236	20 , 6	2 58.93	3 23.6	3 34 46.40	23 13 12.2	9.685	0.669
	3	8 18 52	237	20 , 6	— 4 2.27	3 6.4	3 34 48.54	23 13 15.1	9.689	0.683
	6	7 43 52	238	20 , 6	+ 3 16.41	1 56.5	3 46 14.16	23 31 3.5	9.677	0.644
	6	7 55 11	239	20 , 6	3 2.79	3 41.5	3 46 15.93	23 31 5.8	9.682	0.650
	6	8 5 54	240	20 , 6	+ 2 18.69	1 27.7	3 46 17.69	23 31 7.3	9.686	0.668
	6	8 15 10	241	20 , 6	— 3 29.02	— 0 55.0	3 46 19.29	+23 31 8.0	9.689	0.678

Mean Places for 1898.0 and 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	m s	s	′ ″	″	
1	50 2.64	+4.33	25 25.0	+18.7	*A.N.* 3519
2	54 8.42	4.34	20 22.6	19.0	O. 76, 171
3	48 8.56	4.33	37 30.3	18.5	O. 76, 171
4	52 41.23	4.33	34 5.9	18.8	O. 76, 159
5	53 49.96	4.34	38 35.3	18.9	O. 176
6	47 52.48	4.31	5 21.1	18.5	O. 159
7	47 12.00	4.30	18 5.6	18.4	*A.N.* 3519
8	46 45.21	4.29	53 22.0	18.5	G 28626
9	46 37.11	4.30	18 55.3	18.4	*A.N.* 3519
10	46 1.14	4.26	0 27.0	18.4	G. 28612
11	45 12.36	4.26	15 30.9	18.2	*A.N.* 3519
12	43 18.59	4.25	18 46.2	18.1	*A.N.* 3519
13	42 45.75	4.24	23 52.9	18.3	*A.N.* 3519
14	41 15.57	4.23	21 9.9	17.9	*A.N.* 3521
15	40 35.19	4.24 } +4.03 }	39 50.9	17.8 } +17.9 }	O. 76, 171
16	39 50.98	+4.21	31 37.3	+17.8	*M.N.*
17	35 59.62	4.19	21 38.3	17.5	*A.J.* 453
18	34 46.13	4.18	12 22.6	17.5	*M.N.*
19	38 29.05	4.18	19 15.8	17.9	*M.N.*
20	38 32.83	4.17	57 28.2	18.0	*M.N.*
21	38 57.83	4.18	10 27.7	18.0	*M.N.*
22	37 59.34	4.18 } 4.01 }	35 26.3	17.8 } 17.7 }	*M.N.*
23	37 33.33	4.18	43 55.7	17.7	*M.N.*
24	33 52.52	4.16 } 3.99 }	33 1.2	17.5 } 17.4 }	*M.N.*
25	25 16.29	4.09	13 20.9	16.8	O. 162, 172
26	25 14.27	4.08 } 4.03 }	10 2.9	16.8 } 16.7 }	G 28124
27	25 13.75	+4.08	4 23.3	+16.8	M. 1, 24762

*	α	Red. to app. place	δ	Red. to app. place	Authority
	m s	s	′ ″	″	
28	27 59.82	+3.98 3.96	31 0.0	+16.8 16.9	O. 172
29	29 16.03	3.99 3.98	37 0.7	16.9 17.0	O.76,163,172
30	29 58.63	4.00 3.98	38 25.6	17.0 17.0	O. 76, 163
31	26 32.09	3.93 3.92	56 50.5	17.0 17.0	Gl. I, 5151
32	33 36.75	3.98	26 0.8	17.4	M. I, 25393
33	33 45.22	3.98	30 57.9	17.4	*M.N.*
34	25 10.13	3.91	43 51.0	16.9	G. 28120
35	27 52.51	3.89	19 21.8	16.8	M. I, 24961
36	27 29.17	3.89	16 52.3	16.8	O. 76, 172
37	28 12.81	3.86	42 6.5	17.0	M. I, 24987
38	29 8.29	3.88 3.83	11 31.1	16.9 16.8	G. 28194
39	36 33.15	3.87	14 15.5	17.4	*M.N.*
40	26 41.27	3.79	35 17.9	16.8	G. 28148
41	27 33.01	3.79	40 20.9	16.8	M. II, 10141
42	29 58.18	3.76	52 34.1	17.0	O. 159
43	27 28.87	3.74	31 4.3	16.9	K. II and V
44	30 59.93	3.74	43 45.2	17.2	M. I, 25205
45	35 55.31	3.76	34 5.4	17.6	M. I, 25570
46	37 6.33	3.75	39 38.2	17.7	*M.N.*
47	37 55.56	3.76	31 51.5	17.8	M. I, 25708
48	33 42.96	3.73	17 17.8	17.5	G. 28, 306
49	47 57.27	3.77	32 42.1	18.5	M. II, 10935
50	44 57.40	3.75	29 46.5	18.2	G. 28583
51	49 11.77	3.76	51 6.6	18.4	O. 74, 171
52	49 39.65	3.76	52 4.1	18.4	O. 159, 171
53	55 9.26	3.79	52 29.2	18.9	G. 28792
54	41 51.31	3.71	27 22.8	17.9	G. 28508
55	55 17.50	3.75	45 18.9	18.8	G. 28799
56	42 21.38	3.68	24 2.7	17.9	G. 28517
57	46 26.27	3.69	10 41.5	18.3	G. 28619
58	59 44.00	3.77	34 45.0	19.2	M. II, 11190
59	59 16.23	3.77	30 51.6	19.2	M. II, 11191
60	46 56.39	3.65	5 8.6	18.3	G. 28631
61	51 17.07	3.68	20 58.7	18.6	M. I, 26619
62	50 58.12	3.68	18 10.9	18.6	M. I, 26596
63	55 11.57	3.67 3.66	7 27.2	19.0 19.0	*B.J.*
64	59 23.78	3.69	13 34.5	19.2	M. I, 27116
65	5 52.95	3.73	12 9.3	19.7	M. I, 27504
66	56 29.14	3.66	3 57.2	19.1	*A.J.* 453
67	2 21.00	3.69	2 33.4	19.5	M. I, 27285
68	48 42.61	3.61	55 42.2	18.5	G. 28673
69	12 49.82	3.74	56 52.4	20.3	Gl. 5412
70	2 21.77	3.68	51 16.8	19.6	Sch. 8502
71	0 10.96	3.66	46 5.8	19.4	*A.J.* 453
72	3 24.76	3.68	50 19.0	19.7	M. II, 11258
73	56 19.43	3.62	31 54.4	19.2	Sch. 8445–6
74	7 14.96	3.68	42 54.4	19.9	M. I, 27580
75	16 18.81	3.72	55 10.8	20.5	K. V
76	16 44.41	3.72	52 40.9	20.5	M. I, 28145
77	19 57.78	3.58	59 37.2	20.6	G. 29363
78	24 4.01	3.60	39 33.8	21.0	M. I, 28543
79	16 27.90	3.56	37 58.4	20.5	M. II, 11508
80	19 32.61	3.57	50 6.4	20.6	Gl. 5451
81	17 8.44	3.55	33 50.7	20.5	G. 29307
82	27 47.63	+3.61	38 39.9	+21.2	M. I, 28749

*	α	Red. to app. place	δ	Red. to app. place	Authority
	m s	s	′ ″	″	
83	15 46.77	+3.51	29 32.2	+20.1	M. II, 11497
84	15 52.30	3.51	28 18.1	20.2	M. I, 28093
85	27 14.68	3.60	30 8.2	21.2	M. II, 11720
86	17 7.48	3.53	29 29.3	20.4	M. II, 11522
87	21 11.65	3.55	25 34.7	20.8	*A.N.* 3542
88	27 2.58	3.58	21 2.9	21.2	Gl. 5494
89	51 54.13	3.47	16 0.1	22.4	*A.J.* 453
90	57 18.00	3.50	24 38.8	22.7	G. 30156
91	59 32.67	3.51	23 56.8	22.8	G. 30204
92	51 10.92	3.45	9 50.5	22.3	R. III, 5908
93	52 27.29	3.45	6 42.9	22.4	*A.J.* 456
94	55 17.39	3.47	4 3.8	22.6	C.B. 6064–5
95	0 32.68	3.47	48 55.4	22.9	*B.J.*
96	9 8.23	3.49	27 25.0	23.4	Gl. 5743
97	53 43.73	3.40	23 28.7	22.5	C.B. 6058–9
98	3 26.71	3.45	26 15.0	23.0	Sch. 9032–3
99	56 34.84	3.41	9 20.3	22.7	C.B. 6074–5
100	58 13.52	3.42	13 51.3	22.8	M. I, 30123
101	3 26.84	3.44	9 38.0	23.0	G. 30281
102	6 2.21	3.45	3 1.0	23.2	*A.J.* 453
103	8 6.49	3.46	15 44.8	23.3	R. III, 5975
104	11 32.32	3.47	1 3.0	23.5	C.B.6160–1
105	1 52.89	3.42	4 17.1	23.0	*M.N.*
106	4 10.55	3.43	11 18.8	23.2	C.B. 6117–8
107	8 37.05	3.45	22 23.6	23.4	M. I, 30473
108	16 28.16	3.50	7 49.5	23.8	Sch. 9138–40
109	18 14.76	3.51	5 36.8	23.9	C.B. 6191–2
110	10 25.56	3.45	27 59.8	23.5	Y. 10037
111	13 18.12	3.47	21 40.8	23.6	M. I, 30660
112	17 31.89	3.50	18 29.7	23.8	M. I, 30810
113	11 50.53	3.45	37 48.7	23.6	M. I, 30603
114	15 52.40	3.48	31 32.3	23.8	M. I, 30752
115	18 26.21	3.49	28 0.3	23.9	M. I, 30843
116	23 40.62	3.51	48 27.0	24.2	M. I, 31023
117	23 48.89	3.51	47 8.0	24.2	M. I, 31025
118	24 26.81	3.51	46 26.7	24.2	M. I, 31046
119	20 4.08	3.49	51 35.0	24.0	C. 1590
120	25 9.09	3.45	31 14.8	23.7	A. 7786
121	21 57.30	3.44	33 23.6	23.6	A. 7773
122	21 12.84	3.43	27 2.5	23.5	A. 7770
123	30 18.28	3.45	2 5.5	24.4	A. 7815
124	27 10.72	3.43	3 45.9	24.2	A. 7796
125	39 45.76	3.50	3 10.4	24.8	A. 7866
126	35 17.41	3.46	36 4.9	24.6	A. 7843
127	34 38.60	3.45	42 39.4	24.6	A. 7839
128	37 20.68	3.47	22 6.9	24.6	A. 7852
129	42 18.03	3.50	22 1.7	24.9	A. 7880
130	39 59.14	3.48	50 11.7	24.9	A. 7868
131	44 16.69	3.50	42 11.6	25.0	A. 7889
132	33 18.90	3.44	48 42.5	24.6	A. 7834
133	40 26.99	3.47	5 41.6	24.9	A. 7872
134	43 45.68	3.49	58 17.1	25.0	A. 7887
135	47 21.68	3.51	0 37.6	25.2	A. 7906
136	48 24.67	3.48	41 30.4	25.2	A. 7912
137	49 56.37	3.49	34 5.6	25.2	A. 7915
138	53 29.26	3.52	27 46.7	25.3	A. 7928
1899.0					
139	54 11.15	0.44	49 10.4	6.0	A. 7933
140	56 30.92	0.46	55 18.9	6.0	A. 7946
141	59 49.08	0.47	3 18.5	6.1	A. 7965
142	57 41.02	+0.44	16 47.1	+ 6.1	A. 7951

*	α	Red. to app. place	δ	Red. to app. place	Authority
	m s	s	′ ″	″	
143	0 59.25	+0.46	8 27.4	+ 6.1	A. 7971
144	3 26.72	0.48	7 52.1	6.1	A. 7985
145	57 59.16	0.43	23 48.8	6.0	A. 7954
146	1 38.96	0.45	29 23.2	6.1	A. 7974
147	2 55.35	0.46	19 39.0	6.1	A. 7981
148	2 21.86	0.44	33 10.9	6.0	A. 7978
149	4 52.96	0.46	35 37.3	6.1	A. 7994
150	6 1.38	0.46	39 48.3	6.1	A. 8000
151	3 42.90	0.44	47 26.8	6.0	A. 7987
152	8 1.34	0.46	52 16.7	6.1	A. 8012
153	8 43.84	0.47	44 36.9	6.1	A. 8019
154	5 7.67	0.44	7 13.7	6.1	A. 7996
155	9 51.80	0.47	57 17.4	6.1	A. 8026
156	9 58.12	0.47	56 48.4	6.1	A. 8028
157	14 20.63	0.48	20 1.3	6.2	A. 8047
158	19 13.45	0.51	37 52.3	6.4	Gl. 6171
159	20 13.38	0.54	29 10.1	6.4	Y. 10618
160	27 4.62	0.53	31 45.1	6.5	Gl. 6220
161	31 6.30	0.56	18 10.7	6.5	Gl. 6246
162	33 28.37	0.57	9 55.7	6.5	Gl. 6257
163	14 12.40	0.45	39 46.8	6.2	Gl. 6140
164	34 49.50	0.56	52 40.8	6.6	Gl. 6263
165	36 48.04	0.57	41 31.2	6.6	Y. 10748
166	35 22.26	0.52	16 46.3	6.4	Y. 10737
167	35 30.40	0.52	19 33.9	6.4	Gl. 6267
168	35 33.52	0.52	22 49.7	6.4	Gl. 6268
169	36 32.34	0.52	38 39.2	6.4	Gl. 6271
170	40 3.44	0.53	40 12.3	6.5	Gl. 6286
171	25 46.70	0.46	26 23.1	6.2	Gl. 6210
172	43 2.58	0.54	41 7.4	6.4	Gl. 6309
173	33 43.85	0.49	45 14.7	6.3	Gl. 6259
174	30 27.22	0.47	49 30.6	6.3	Gl. 6244
175	39 21.78	0.51	56 42.2	6.4	Gl. 6282
176	47 32.71	0.55	9 32.3	6.6	Gl. 6335
177	30 18.88	0.47	57 40.5	6.2	Gl. 6242
178	49 12.68	0.55	34 55.6	6.5	Gl. 6344
179	53 35.07	0.57	40 56.8	6.6	Gl. 6372
180	57 13.75	0.59	23 40.8	6.6	Y. 10917
181	13 5.38	0.58	38 46.4	6.6	Gl. 74
182	13 38.50	0.57	43 46.0	6.5	Kl. 69
183	4 50.64	0.53	35 1.9	6.4	Gl. 21
184	3 20.34	0.52	36 32.2	6.4	Gl. 9
185	26 27.80	0.61	21 38.7	6.8	M. II, 142
186	28 24.60	0.62	6 52.6	6.8	M. II, 155
187	15 46.43	0.55	12 40.9	6.6	Y. 114
188	15 58.52	0.55	9 12.0	6.6	Y. 150
189	31 17.56	0.61	42 58.3	6.8	Gl. 161
190	30 41.14	0.61	39 25.7	6.8	Gl. 159
191	29 41.27	0.60	48 56.7	6.8	Gl. 155
192	38 8.60	+0.62	22 38.9	+ 6.8	Gl. 193

*	α	Red. to app. place	δ	Red. to app. place	Authority
	m s	s	′ ″	″	
193	47 11.52	+0.67	6 0.1	+ 6.9	W. 189
194	50 51.17	0.69	24 17.1	7.0	Gl. 239
195	54 25.32	0.66	3 53.3	6.9	W. 222
196	47 51.65	0.63	55 29.2	6.8	Sch. 307
197	44 24.75	0.61	54 58.2	6.7	Kl. 254
198	59 45.40	0.67	24 10.9	6.8	W. 252
199	0 28.67	0.67	26 29.5	6.8	W. 257
200	4 49.97	0.68	8 12.9	6.8	B_1 329
201	5 8.71	0.68	7 50.3	6.8	B_1 333
202	12 30.99	0.72	6 53.9	6.9	B_1 365
203	22 8.12	0.73	15 50.4	7.0	B_1 417
204	13 58.84	0.69	8 31.6	6.9	B_1 372
205	16 58.94	0.70	17 56.1	6.9	B_1 389
206	33 40.95	0.72	4 43.2	6.8	B_1 471
207	35 20.12	0.73	57 4.4	6.8	B_1 478
208	28 3.96	0.70	7 41.3	6.8	B_1 452
209	28 20.14	0.70	10 1.1	6.8	B_1 454
210	33 36.61	0.70	33 37.5	6.7	B_1 470
211	35 4.97	0.71	21 35.3	6.7	B_1 476
212	43 16.76	0.75	17 5.5	6.7	B_1 519
213	7 17.30	0.82	20 50.8	6.8	B_1 618
214	10 38.00	0.84	13 20.7	6.7	B_1 632
215	12 17.87	0.84	12 49.8	6.7	B_1 640
216	13 31.78	0.85	13 35.4	6.7	B_1 642
217	11 33.66	0.81	35 1.4	6.7	B_1 635
218	12 30.34	0.82	26 2.2	6.6	B.J.
219	14 54.81	0.83	39 38.7	6.7	B_1 646
220	22 8.95	0.82	3 14.6	6.4	B_1 677
221	25 55.71	0.84	12 34.4	6.5	B_1 689
222	24 56.23	0.82	25 55.5	6.4	B_2 754
223	23 40.87	0.82	23 41.2	6.4	B_2 750
224	30 29.72	0.85	26 42.5	6.4	B_2 784
225	39 24.22	0.88	57 20.9	6.3	B_2 822
226	31 44.71	0.84	51 13.6	6.3	B_2 789
227	31 52.52	0.84	58 49.4	6.3	B_2 791
228	34 56.51	0.85	47 19.3	6.2	B_2 803
229	51 16.33	0.89	47 26.6	6.2	B_2 862
230	11 56.84	0.92	27 45.2	5.7	B_2 972
231	11 4.64	0.91	27 41.0	5.7	B_2 966
232	11 22.77	0.92	35 3.2	5.7	B_2 969
233	16 38.22	0.94	26 51.3	5.6	B_2 999
234	35 24.99	1.00	9 45.1	5.2	B_2 1097
235	37 42.86	1.02	19 45.8	5.2	B_2 1108
236	37 44.31	1.02	16 30.6	5.2	B_2 1109
237	38 49.79	1.02	16 16.3	5.2	B_2 1120
238	42 56.74	1.01	32 54.8	5.2	B_2 1192
239	43 12.12	1.02	34 42.1	5.2	B_2 1197
240	43 57.98	1.02	32 29.9	5.1	B_2 1212
241	49 47.26	+1.05	31 58.0	+ 5.0	B_2 1219

NOTE. — On account of the unusual multiplicity of comparison-stars employed by the author, it has been necessary to condense by omitting the unessential details of the hour in α, and degree in δ, and to express the authority by the following synonyms —

A.N. = *Astr. Nachr.*
A.J. = *Astr. Journal*
B.J. = *Berl. Jahrb.*
A = Boss, Albany, A.G.
B_1 = Auwers, Berlin, A.G.
B_2 = Becker, Berlin, A.G.
C. = Cape 1885
C.B. = Copeland-Börgen
G. = Gould Gen. Catal.
Gl. = Glasgow I
K = Karlsruhe
Kl. = Klinkerfues, Gott. Z.
M = Munich
M.N. = *Monthly Not.*, Nov. or Dec 1898
O. = Ottakring Zones
R.III = Radcliffe III
Sch. = Schjellerup
W = Washington II
Y = Yarnall

ED.

NOTES.

1898 *Sept.* 19th, Asteroid faint in haze; wind shook telescope. — 22d, Asteroid faint in haze and moonlight. — 26th, Asteroid scarcely visible; moon near. — 29th, Asteroid connected by micrometric measures with a faint star near by, which was afterward connected with ✱26. — *Oct.* 24th, Asteroid difficult in moonlight and bad seeing. — 25th, The observations of the third set are poor. — *Nov.* 3d, Asteroid hard to see in haze; at $6^h\ 34^m$ M.T. it coincided so nearly with a 12.5 mag. star, that they seemed to be one. — 4th, Bad seeing. — *Dec.* 5th, Poor seeing. — 17th, Observations difficult from haze and moonlight. — 1899 *Jan.* 6th, The declination measures of the third set disagree very badly. — 7th, The third set of observations is poor, because of haze. — 20th, Asteroid very faint in haze and moonlight during the third set. — 23d, Wind shook the telescope during the third set. — *Feb.* 1st, Very bad seeing. — 9th, Poor seeing. — 16th, Much difficulty from clouds and moonlight. — 23d, Asteroid very hard to see; bad definition. — *Mar.* 1st, Asteroid extremely faint through a cloud, during the first set. — 11th, Asteroid faint in a cloud during the first two sets. — 14th, Bad seeing; windy; moon within three degrees of the planet. — 15th, The $\Delta\delta$ observations of the first set were made with the driving clock running. — 23d, Observations quite difficult in haze and moonlight. — 28th, The $\Delta\delta$ observations of the first set were made with the driving clock running. — *Apr.* 6th, Poor seeing throughout the evening.

REMARKS ON MR. MOULTON'S PAPER IN *A.J.* 461,

BY T. J. J. SEE.

In the interesting application which Mr. MOULTON has made of the criteria of stability to the irregularity in the system of F. 70 *Ophiuchi*, he speaks as if his results rendered the hypothesis of a perturbation improbable. Those who will examine my original papers in *A.J.* 358, 363, will see that I foresaw from the first the difficulty of securing stability, and that while I assigned the unseen body to the companion, partly because it seemed unwise to introduce prolix hypotheses when many still disputed the *fact* of a perturbation, and partly because with the graphical method employed the perturbation would be more obvious if assigned to the small star, I never entertained any very decided view as to which star the dark body attended. Under (9) *A.J.* 363, I remarked: "While we have spoken of the dark body as attending the companion, it is clear that similar phenomena would result from the action of a body revolving round the central star." And in the volume on *orbits*, which appeared shortly afterwards, I had so far reached the conclusion that the large star is perturbed, that I gave the place of the dark body referred to that star. In the recent examinations of this system made in Arizona I always assumed that the dark body attends the central star, and on several occasions suspected an obscure satellite in position-angle 160°, but could never confirm the suspicion even under those fine conditions.

* * * * * * * *

U.S. Naval Observatory, Washington, D.C., 1899 *May* 18.

NOTE. — The remainder of Dr. SEE's communication is omitted, partly because it has no pertinent bearing on Mr. MOULTON's paper. To abbreviate most effectively unfruitful discussion, Dr. SEE's remarks were transmitted to Mr. MOULTON to afford him opportunity, if he desired, to reply; but he declines, on perfectly correct and dignified grounds, to do so; his essential and sufficient reason being that the statements are not in accordance with the facts.

Here the matter might be dropped were it not desirable to direct the attention of those who care to consider the matter further, to the remainder of Dr. SEE's paragraph in *A.J.* 363, of which he here quotes only four lines; and also to the fact that his book of computations of orbits of double stars merely reproduces, without addition or subtraction of a word or line, his article in *A.J.* 363. It therefore affords no evidence of change of view or modification of hypothesis.

The present is as fitting an opportunity as any to observe that heretofore Dr. SEE has been permitted, in the presentation of his views in this journal, the widest latitude that even a forced interpretation of the rules of catholicity would allow; but that hereafter he must not be surprised if these rules, whether as to soundness, pertinency, discreetness or propriety, are construed within what may appear to him unduly restricted limits.

ED.

CORRIGENDA.

No. 456, line 9, column δ, *for* 32″.7 *put* 39″.9.
" " " 11, " α, *for* $58^s.26$ *put* $59^s.59$.
" " " 15, " δ, *for* 14″.4 *put* 17″.7.
No. 459, in column "Authority" for stars 3, 4 and 5, *for* Rogers *put* Graham. (This error was the Editor's, not the contributor's.)

CONTENTS.

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NOTES ON VARIABLE STARS, — No. 28,

BY HENRY M. PARKHURST.

A New Variable in Aquila. My observations indicate that DM. +15°4082 is a variable with the approximate elements 5587.60 + 7.90 *E*. There are several observations so discordant as to be rejected, and many varying more than half a day from the mean curve. At the first glance, in the second observation of Oct. 31, the remarkable change of brightness was noticed. The mean maximum is $8^{M}.43$, and the mean minimum $9^{M}.20$. $M - m = 2.90$. The comparison star $1a, 5'$ *up V*, is omitted from the DM., and being brighter than *V* is liable to be mistaken for it. A majority of the few scattered observations in 1896 and 1897, before the periodicity was ascertained, are in satisfactory accord with these elements· but a large minority vary more than a day.

RESULTS OF OBSERVATIONS.

No.	Star	Phase	Observed Date Julian	Observed Date Calendar	E	Corr.	W	Mag.	S Factors			Remarks
				1898							d	
7155	*RR Aquilae*	Max.	4507	Aug. 5	3	– 78	6	7.65	–	–	–	Rises rapidly
7162	*RS Aquilae*	Max.	4588	Oct. 25	–	–	7	9.38	1.58	2.20	27	206? instead of 218
	DM. +4°4332	–	–	–	–	–	–	–	–	–	–	"Missing;" *A.J.* 386
7234	*R Capricorni*	Max.	4481	July 10	11	– 54	3	11.1	–	–	–	Long interruptions
	– *Aquilae* = DM. +15°4082	Max.	4587.6	Oct. 24	0	0.0	6	8.43	0.13	0.20	1	See note above
		Min.	4593.2	Oct. 30	1	+ 0.6	6	9.20	0.20	0.13	4	Second obs. Oct. 31 rejected
	"	Max.	4595.3	Nov. 1	1	– 0.2	6	8.41	–	–	3	
	"	Min.	4600.7	Nov. 6	2	+ 0.2	6	9.27	–	–	–	
	"	Max.	4635.6	Dec. 11	6	+ 0.6	6	8.43	–	–	4	Obs. Dec. 11 rejected
	"	Min.	4639.8	Dec. 15	7	– 0.2	6	9.20	–	–	2	No consecutive obsns.
	"	Max.	4642.5	Dec. 18	7	– 0.4	3	8.42	–	–	1	Possible after Oct. 16
	"	Min.	4647.5	Dec. 23	8	– 0.4	3	9.22	–	–	1	
	"	Max.	4650.8	Dec. 26	8	0.0	6	8.43	–	–	5	
7252	*W Capricorni*	Max.	4569	Oct. 6	46	+ 30	8	12.20	2.54	1.49	26	Fluctuating
7260	*Z Aquilae*	Max.	4533	Aug. 31	11	– 11	7	8.97	1.52	1.62	32	
7261	*R Delphini*	Max.	4460	June 19	42	– 6	2	10.1	–	–	–	Perhaps earlier
7435	*Y Aquarii*	Max.	4481	July 10	–	–	1	8.6	–	–	–	390?
7468	*T Aquarii*	Max.	4509	Aug. 7	66	– 8	2	8.0	–	–	–	
7502	*X Delphini*	Max.	4555	Sept. 22	–	–	9	9.24	1.19	1.01	13	280?
7590	*Z Capricorni*	Max.	4586	Oct. 23	3	–112	6	9.28	0.58	1.61	24	—26, from per. *A.J.* 372
7896	*V Pegasi*	Max.	4579	Oct. 16	4	+ 1	6	9.39	–	–	–	From elements in following note
7907	*U Aquarii*	Max.	4625	Dec. 1	33	+ 6	1	10.6	–	–	–	See following note
7909	*S Pisc. Austr.*	Max.	4596	Nov. 2	11	– 16	7	9.00	0.84	1.85	18	Faint
7999	*X Aquarii*	Max.	4639	Dec. 15	4	+ 31	9	8.66	3.66	1.16	26	
8290	*R Pegasi*	Max.	4560	Sept. 27	16	– 12	9	9.55	0.78	1.02	17	
8369	*W Pegasi*	Max.	4525	Aug. 23	–	–	E	–	–	–	–	Prov. per. 347, light-curve
"	"	Min.	4699	Feb. 13	–	–	E	–	–	–	–	
8373	*S Pegasi*	Max.	4598	Nov. 4	39	+ 6	9	8.62	0.98	0.85	16	
8512	*R Aquarii*	Max.	4566	Oct. 3	82	– 13	9	6.48	0.50	1.63	12	
8597	*V Ceti*	Max.	4621	Nov. 27	27	– 16	8	8.58	1.34	1.75	21	
8622	*W Ceti*	Max.A	4629	Dec. 5	3	– 21	7	8.82	–	–		Corresponds with last year
"	"	Max.B	4682	Jan. 27	3	+ 32	7	8.06			–	Higher max. approaching

V Pegasi. Adopting for the epoch 3346, the highest observation in the Harvard series of forty observations, and for the period 308 days, assigned by J. A. Parkhurst in *A.J.* 405, my two maxima, in 1897 and 1898, make the corrections 0 and +1, respectively.

U Aquarii. From Aug. 2 to Dec. 21, 1886, the variable remained invisible; 7 observations. Predicted maximum Nov. 22. This seems to me to outweigh all the evidences of periodicity.

Individual Observations.

Including Observations by Arthur C Perry.

7155 *RR Aquilae.*

(Cont. from 425. Comp. Stars 393)

Julian	Calendar	Mag.
	1898	
4464.6	June 23	11.0]
4481.7	July 10	9.3
4501.6	Aug. 2	7.47_2
4507.6	5	7.72_2
4515.6	13	7.58_2
4517.6	15	8.16_2
4533.6	31	7.97_2
4539.6	Sept. 6	7.89_2
4543.5	10	8.05_2
4546.5	13	8.28_2
4550.5	17	8.35_3
4554.5	21	8.02
4561.5	28	8.41_2
4579.5	Oct. 16	9.46_2
4586.5	23	9.57_2

7162 *RS Aquilae.*

(Cont. from 425. Comp. Stars.)

Julian	Calendar	Mag.
	1898	
4481.7	July 10	13]
4539.6	Sept. 6	13]
4542.6	9	13]
4551.5	18	13:
4572.5	Oct. 9	9.9
4573.5	10	9.57
4579.5	16	9.72_2
4586.5	23	9.40_2
4595.5	Nov. 1	9.59_2
4601.5	7	9.54_2
4606.5	12	9.55_2
4615.5	21	9.97_2

DM. +4°4332.

3862 Oct. '96 to
4605 Nov. '98 10
12 dates

7234 *R Capricorni.*

(Cont. from 425. Comp. Stars.)

Julian	Calendar	Mag.
	1898	
4481.7	July 10	11.1
4489.7	18	11.55_2
4517.6	Aug. 15	11.68_2
4537.6	Sept. 4	11.87_2

— *Aquilae.*

DM. +15°4082

Julian	Calendar	Mag.
	1896	
3873.5	Nov. 9	7.10_2
3879.5	15	8.25_2
3886.5	22	8.75_2
3895.5	Dec. 1	9.08_2
3901.4	7	8.85_2
3904.5	10	9.0P

— *Aquilae.*—Cont.

Julian	Calendar	Mag.
	1896	
3907.5	Dec. 13	8.64_2
3911.5	17	8.61_2
3914.5	20	9.0_2P
3918.5	24	9.2P
3924.5	30	8.66_2
	1897	
4114.6	July 8	8.3
4161.6	Aug. 24	8.8
4174.5	Sept. 6	8.64
4182.6	14	8.40
4189.5	21	8.36
4194.5	26	8.52
4200.5	Oct. 2	8.77
4210.6	12	8.87
4215.5	17	8.33
4221.5	23	8.95
4247.5	Nov. 18	8.79
4283.5	Dec. 24	8.63
	1898	
4488.6	July 17	8.13_3;
4541.6	Sept. 8	8.79_2
4574.5	Oct. 11	8.79_2
4585.6	22	8.58_2
4586.5	23	8.59_2
4587.5	24	8.44_2
4590.5	27	9.04_2
4591.5	28	9.00_2
4593.6	30	9.15_2
4594.5	31	8.43_2
4594.6	31	8.84_3
4595.5	Nov. 1	8.41_2
4596.5	2	8.61_2
4597.5	3	8.73_3
4598.5	4	8.73_3
4600.5	6	9.27_3
4601.5	7	8.96_2
4609.5	15	8.92_2
4610.5	16	8.79_4;
4615.5	21	8.64_2
4619.5	25	8.50_5
4631.5	Dec. 7	9.09_5
4632.5	8	8.75_5
4633.5	9	8.74_5
4635.5	11	9.21_5
4637.5	13	8.57_5
4638.5	14	8.96_5
4639.5	15	9.16_5
4640.5	16	8.98_5
4642.5	18	8.42_5
4647.5	23	9.22_5
4650.5	26	8.49_5
4652.5	28	8.83_5

7252 *W Capricorni.*

(Continued from 425.)

Julian	Calendar	Mag.
	1898	
4538.6	Sept. 5	13.0
4544.6	11	12.27_2
4545.6	12	12.71_2
4546.6	13	12.16_2
4551.5	18	12.15_2
4552.5	19	12.47_2
4554.5	21	12.37_2
4569.5	Oct. 6	12.21_2
4575.5	12	12.30_2
4579.5	16	12.26_2
4580.5	17	12.79_2

7260 *Z Aquilae.*

(Cont. from 425. Comp. Stars 393)

Julian	Calendar	Mag.
	1898	
4464.6	June 23	10.5]
4481.7	July 10	9.9
4508.6	Aug. 6	9.94_2
4517.6	15	9.00_2
4537.5	Sept. 4	9.18_2
4541.5	8	8.95_2
4543.5	10	9.08_2
4546.5	13	9.25_2

7261 *R Delphini.*

(Continued from 425.)

Julian	Calendar	Mag.
	1898	
4458.6	June 17	10.1P
4462.6	21	10.1P
4481.6	July 10	11.0P
4507.6	Aug. 5	11.2P

7435 *Y Aquarii.*

(Continued from 425.)

Julian	Calendar	Mag.
	1898	
4481.6	July 10	8.6
4489.6	18	9.2
4508.6	Aug. 6	9.35_2
4517.6	15	9.44
4538.5	Sept. 5	9.51_2
4544.5	11	9.71_2
4550.5	17	9.66_2
4552.5	19	9.73_2
4579.5	Oct. 16	11.7

7468 *T Aquarii.*

(Cont. from 431. Comp. Stars 438)

Julian	Calendar	Mag.
	1898	
4481.7	July 10	8.7
4481.7	10	8.2P
4508.6	Aug. 6	8.03
4517.6	15	8.33_2
4533.6	31	8.39_2

7502 *X Delphini.*

(Cont. from 431. (Comp. Stars 438)

Julian	Calendar	Mag.
	1898	
4481.7	July 10	13]
4539.6	Sept. 6	10.1
4541.6	8	9.58_2
4542.5	9	9.40_2
4545.5	12	9.40_2
4549.5	16	9.39_2
4552.5	19	9.34_2
4556.5	23	8.98_2
4559.5	26	9.40
4561.5	28	9.44_2
4564.5	Oct. 1	9.47_2
4570.5	7	9.23_2
4580.5	17	9.67_2

7590 *Z Capricorni.*

(Cont. from 431 Comp. Stars 372)

Julian	Calendar	Mag.
	1898	
4545.5	Sept. 12	11.8
4572.5	Oct. 9	10 1
4575.5	12	10.00_2
4583.5	20	9.47_2
4587.5	24	9.21_2
4595.5	Nov. 1	9.52_2
4601.5	7	9.70
4606.5	12	9.59_2
4637.5	Dec. 13	11.8

7896 *V Pegasi.*

(Continued from 431.)

Julian	Calendar	Mag.
	1898	
4569.5	Oct. 6	9.4
4570.5	7	9.40_2
4575.6	12	9.58_2
4580.5	17	9.26_2
4585.5	22	9.52_3
4590.5	27	9.74_2

7907 *U Aquarii.*

(Continued from 314.)

Julian	Calendar	Mag.
	1898	
4538.6	Sept. 5	11.8
4539.5	6	11.46_2
4554.5	21	11.81
4576.5	Oct. 13	11.06_2
4605.5	Nov. 11	10.76
4625.5	Dec. 1	10.63

7909 *S. Pisc. Austr.*

(Cont. from 372. Comp. Stars 372)

Julian	Calendar	Mag.
	1898	
4587.6	Oct. 24	9.54_2
4595.5	Nov. 1	8.77_2
4600.5	6	9.06_2
4601.5	7	9.20_2
4606.5	12	8.95_2
4614.5	20	9.32_2
4615.5	21	9.47_2

7999 *X Aquarii.*

(Continued from 431.)

Julian	Calendar	Mag.
	1898	
4572.5	Oct. 9	12:
4576.5	13	11.43_2
4580.5	17	10.47_2
4586.5	23	10.12_2
4595.5	Nov. 1	9.93_2
4601.5	7	9.33_2
4606.5	12	9.20_2
4614.5	20	8.93_2
4615.5	21	8.73_2
4619.5	25	8.70_2
4624.5	30	8.86_2
4630.5	Dec. 6	8.83_2
4637.5	13	8.64_2
4647.5	23	8.56_2
4650.5	26	9.12_2
4653.5	29	9.40_2

8290 *R Pegasi.*

(Continued from 400.)

Julian	Calendar	Mag.
	1898	
4546.5	Sept. 13	9.0
4553.5	20	9.40_4
4554.5	21	9.78_2
4556.5	23	9.65_2
4560.5	27	9.37_2
4563.5	30	9.63_2
4570.5	Oct. 7	9.51_2
4576.5	13	10.37_2
4580.5	17	10.62_2

8369 *W Pegasi.*

(Continued from 431.)

Julian	Calendar	Mag.
	1898	
4574.5	Oct. 11	9.8
4583.5	20	10.58_2
4597.5	Nov. 3	10.7
4632.5	Dec. 8	11.0:P

8373 *S Pegasi.*

(Cont. from 431. Comp. Stars.)

Julian	Calendar	Mag.
	1898	
4546.5	Sept. 13	10.3
4576.5	Oct. 13	9.54_2
4580.5	17	9.34_2
4586.6	23	9.17_2
4595.5	Nov. 1	8.39_2
4598.5	4	8.55_2
4600.5	6	8.67_2
4601.5	7	8.77_2
4608.5	14	8.80_2
4614.5	20	8.93_2
4632.5	Dec. 8	9.2P

8512 *R Aquarii*.
(Continued from 431.)

Julian	Calendar 1898	Mag.
4554.5	Sept. 21	·7.7
4556.6	23	7.40_2
4560.6	27	7.06_2
4561.6	28	6.82_2
4562.5	29	6.84_2
4563.5	30	6.54_2
4564.5	Oct. 1	6.25_2
4569.6	6	6.66_2
4572.5	Oct. 9	6.57_2
4575.5	12	6.59_2
4583.5	20	6.62_2

8597 *V Ceti*.
(Continued from 400.)

Julian	Calendar 1898	Mag.
4608.5	Nov. 14	8.90_2
4614.6	20	8.65_2
4619.5	25	8.61_2
4624.5	Nov. 30	8.47_2
4631.5	Dec. 7	8.72_2
4635.5	11	8.80_2
4639.5	15	8.80_2

8622 *W Ceti*.
(Continued from 431.)

Julian	Calendar 1898	Mag.
4597.5	Nov. 3	9.86_2
4600.6	6	9.83_2
4608.5	Nov. 11	9.64_2
4614.5	20	8.99_2
4624.5	30	8.81_2
4630.5	Dec. 6	8.81_2
4637.5	13	8.99_2
4650.5	26	8.96_2
	1899	
4662.5	Jan. 7	8.44_2
4672.5	17	8.47
4673.5	Jan. 18	8.38_2
4675.5	20	$8.4[illegible]_2$
4677.5	22	8.67_2
4680.5	25	7.80_2
4682.5	27	8.00_2
4685.5	30	8.51_2
4690.5	Feb. 4	7.66_2

Comparison-Stars, 1893–1898.

7162 *RS Aquilae*.

Star	DM.	Mag.	n
U	−8°5185	8.50	19
W	−8°5183	9.45	27
X	−7°5127	9.66	16
Y	−8°5188	9.87	14
1 *Y*	−8°5190	10.25	10
a	1.3*s*0.1*p Y*	10.75	4
f	1.0*n*1.4*f Y*	11.74	2
g	0.1*s*1.6*f Y*	11.86	1
h	1.8*s*4.3*p V*	12.11	6
k	0.1*n*3.5*p Y*	12.60	3
l	0.5*s*5.5*p V*	12.86	1

7231 *R Capricorni*.

Star	DM.	Mag.	n
K	−14°5670	8.06	8
N	−14°5661	.8.40	8
Q	−15°5547	8.58	1
R	−14°5654	8.55	12
T	−14°5652	9.37	10
V	−14°5666	9.36	15
Y	−14°5658	11.10	35
Z	−14°5656	11.16	36
1*Z*	−14°5660	11.21	19
h	5*s*7*p Y*	11.66	4
i	6*f Y*	11.99	21

7242 *S Aquilae*.

Star	DM.	Mag.	n
R	+15°4082	var.	
W	+15°4075	9.16	18
X	+15°4070	9.27	4
2*X*	+15°4076	9.22	2
Y	+15°4079	8.89	25
2 *Y*	+15°4080	9.48	23
a	8*s*2*f Y*	9.72	8
1*a*	4*n*4*p R*	8.29	34
b	4*n*3*p V*	10.14	16
1*b*	2*s*5*f R*	9.50	27
d	4*s Y*	10.10	7

8373 *S Pegasi*.

Star	DM.	Mag.	n
P	+8°5041	8.81	0
S	+8°5042	9.35	19
X	+8°5045	9.77	17
Y	+8°5046	10.04	4
a	4*s*4*f S*	9.82	22
b	2*f Y*	11.06	3
f	5*s*6*f X*	11.54	3
j	7*s*2*p S*	12.44	14
k	2*s*5*p Y*	12.70	11
l	4*s*1*p Y*	13.08	6
m	5*s Y*	13.18	5

DISCOVERY OF TWO NEW SOUTHERN VARIABLE STARS,

BY R. T. A. INNES.

[Communicated by Dr. DAVID GILL, H.M. Astronomer.]

Cape 1880 N. 8527 (1875) $15^h\ 34^m\ 26^s.5$ $-54°\ 35'.1$

In looking down the columns of the Cape Photographic DM. I noticed that this star had not been observed in the Cordoba Zones, although other bright neighboring stars had not escaped Dr. GOULD's scrutiny. The star might therefore be variable. My first observation practically settled the question in the affirmative. This star was observed here thrice in 1876 with the Transit Circle, its magnitude being recorded as 6, 6–7 and 6–7 respectively. Below, these magnitudes are roughly reduced to the Cordoba scale. Not being a Lacaille star, Cape 1880, 8527 was no doubt added to the T.-C. working list on account of its brightness at the time that the neighboring star Lac. 6482 was observed. Hence, it may be that a maximum occurred about that time.

We have

1876 July 15	Maximum		(A guess)
Aug. 2	7.0		Cape T.-C.
4	7.3		"
6	7.3		"
(Plate 437)	7.9		C.P.D.
1899 Feb. 18	11.0	(2 faint stars near)	I
20	10.5		I
1899 Feb. 21	10.3		I
Mar. 9	9.7		I
21	9.5		I
Apr. 23	7.3	yellow = 4	I

On account of the yellowness of this star the photographic magnitude will be less than the visual.

C.P.D. −35°, 7270 (1875) $17^h\ 39^m\ 56^s.0$ $-35°\ 39'.1$

This star (C.P.D. mag. = 9.5) is close to C.P.D. −35°, 7267, mag. 9.2, but the latter only occurs in the Cordoba DM. where its magnitude is given as 9.7. As I found the former much the brighter it was kept under observation for variability with the following result:

(C. P. D. −35°,7267 taken = $9^M.6$).

	M		M
1898 July 20	9.25	1898 Oct. 12	10.6
25	9.2	15	10.4
Aug. 4	9.3	17	10.4
Sept. 5	9.5	24	10.7
30	10.5	Nov. 12	inv. under 10
Oct. 7	10.5	1899 Apr. 23	9.1
8	10.7		

Referring to the "Notes on Southern Variable Stars" in *A.J.* 412, the star C.Z. XVI, 911, does not exist; my observations belong to a near star which is not variable.

Royal Observatory, Cape of Good Hope, 1899 *April* 24.

EPHEMERIS OF COMET 1898 VII,

BY C. J. MERFIELD.

The appended ephemeris of this comet has been prepared anticipating that further observations may be obtained. From certain information received by the computer, there would appear to be every probability of this apparition being observed as a morning object during July next.

The data used in preparing the ephemeris are the co-ordinates of the comet computed from my hyperbolic elements (*A.N.* 3546), combined with the co-ordinates of the sun derived from the Nautical Almanac.

EPHEMERIS — GREENWICH MEAN NOON.

Date, 1899	App. α	App. δ	log Δ
	h m s	° ′ ″	
June 24	4 44 27.23	−1 25 59.8	0.6616
26	4 46 5.98	1 16 11.8	
28	4 47 43.18	1 6 46.3	0.6631
30	4 49 18.80	0 57 42.8	
July 2	4 50 52.78	0 49 1.2	0.6642
4	4 52 25.09	0 40 41.0	
6	4 53 55.66	0 32 41.7	0.6650
8	4 55 24.46	0 25 2.8	
10	4 56 51.42	0 17 44.1	0.6656
12	4 58 16.49	0 10 45.0	
14	4 59 39.63	−0 4 4.9	0.6659
16	5 1 0.78	+0 2 16.4	
18	5 2 19.89	0 8 19.6	0.6659
20	5 3 36.93	0 14 5.0	
22	5 4 51.86	0 19 33.1	0.6657
24	5 6 4.63	0 24 44.4	
26	5 7 15.20	0 29 39.1	0.6652
28	5 8 23.51	0 34 17.7	
30	5 9 29.50	0 38 40.5	0.6644
Aug. 1	5 10 33.11	0 42 48.0	
3	5 11 34.28	0 46 40.6	0.6634
5	5 12 32.94	0 50 18.6	
7	5 13 29.04	0 53 42.7	0.6622
9	5 14 22.50	0 56 53.3	
11	5 15 13.25	0 59 50.9	0.6607
13	5 16 1.26	1 2 36.1	
15	5 16 46.46	+1 5 9.3	0.6591

Date, 1899	App. α	App. δ	log Δ
	h m s	° ′ ″	
Aug. 17	5 17 28.80	+1 7 31.1	
19	5 18 8.22	1 9 41.8	0.6572
21	5 18 44.69	1 11 42.1	
23	5 19 18.12	1 13 32.4	0.6552
25	5 19 48.50	1 15 13.2	
27	5 20 15.73	1 16 44.9	0.6531
29	5 20 39.76	1 18 7.9	
31	5 21 0.53	1 19 22.9	0.6507
Sept. 2	5 21 17.95	1 20 30.5	
4	5 21 31.98	1 21 31.4	0.6483
6	5 21 42.56	1 22 26.0	
8	5 21 49.65	1 23 15.0	0.6458
10	5 21 53.19	1 23 59.2	
12	5 21 53.14	1 24 39.1	0.6432
14	5 21 49.47	1 25 15.4	
16	5 21 42.16	1 25 48.9	0.6406
18	5 21 31.15	1 26 19.9	
20	5 21 16.44	1 26 49.2	0.6379
22	5 20 57.99	1 27 17.5	
24	5 20 35.79	1 27 45.3	0.6353
26	5 20 9.84	1 28 13.3	
28	5 19 40.09	1 28 42.3	0.6328
30	5 19 6.54	1 29 12.9	
Oct. 2	5 18 29.18	1 29 46.0	0.6303
4	5 17 47.98	1 30 22.3	
6	5 17 2.92	+1 31 2.7	0.6280

Sidney, N.S. Wales, 1899 *May* 10.

THE DOUBLE HEAD OF COMET *a* 1899 (SWIFT),

BY E. E. BARNARD.

On examining SWIFT's comet with the 40-inch on May 20th, I was struck with the appearance of the head. It was distinctly double. There was a second and smaller condensation — exactly similar to the main condensation — preceding and south, which gave the head the appearance of a double and somewhat unequal nebula. This has been measured for the past four mornings and the smaller condensation is decreasing its position-angle several degrees a day, and the distance between the two components seems to be increasing — probably an effect of perspective.

Though well seen on the 21st, the smaller one was less distinct, perhaps due to increased moonlight. It was still fairly well seen on the 22d but difficult to measure. On the 23d the increase of moonlight and a white sky made it excessively difficult, and the measures are uncertain on that date.

Yerkes Observatory, Williams Bay, Wis., 1899 *May* 24.

Following are the measures obtained — the smaller body being referred to the larger:

1899 May 20d	15h 2m 20s	P.A. = 241°.9 (4)
	15 16 13	Dist. = 28″.84 (9)
21	12 38 55	P.A. = 238°.9 (5)
	13 12 11	Dist. = 30″.81 (11)
22	13 8 45	P.A. = 234°.1 (5)
	13 18 45	Dist. = 35″.07 (6)
23	14 35 0	P.A. = 228°.0 (4)
	14 40 0	Dist. = 38″.16 (3)

The comet has been quite noticeable to the naked eye. On May the 18th it was estimated to be $5\frac{1}{2}^{M}$. Though there is no decided tail as seen with the naked eye, a photograph showed a slender tail 6° or 8° long on the above date.

MEASURES OF A SECOND NUCLEUS IN COMET α 1899 (SWIFT),

BY C. D. PERRINE.

After passing perihelion this comet showed such an increase of brightness and other evidences of internal action that it was carefully examined with the 36-inch refractor for changes in the nucleus, which was very bright and well condensed. It was first observed on the morning of May 7, using a power of 270. The seeing was not good, the star images being considerably blurred. Following are notes made at the time.

"No structure to be detected in the coma. The nucleus is sharp and under the atmospheric conditions existing does not differ from a star. Nucleus fully 7th magnitude, possibly brighter. North preceding the nucleus there is a small appendage brighter than the surrounding coma — about 10″ in length and half as wide. The head of the comet fills the entire field, using a power of 270."

The comet was observed the following night, the appearance being practically the same.

It was next examined on May 11, when a second nucleus was distinctly visible. This second nucleus was about one and one-half magnitudes fainter than the principal nucleus, being estimated at $8^M.0$ and $9^M.5$. Neither nucleus was stellar with a power of 270 and still less sharp with a power of 520.

Following are the measures of position-angle and distance of the fainter nucleus referred to the brighter:

Gr. M.T.	°	″
1899 May 11.99	263.5	12.5
12.96	261.0	14.3
13.98	260.0	16.5
14.96	256.6	18.2

During the interval, May 11 to 14, the distance between the earth and comet has diminished about one-tenth, which would account for a portion of the increase in apparent distance between the nuclei were they relatively fixed. The greater portion of the observed increase in distance in all probability corresponds to an actual separation of the two portions.

Lick Observatory, University of California, 1899 *May* 15.

OBSERVATIONS OF *EROS*,

BY WILLIAM J. HUSSEY.

The following observations of *Eros* have been made with the 12 and 36-inch refractors of the Lick Observatory. Whenever the planet and a catalogued star were sufficiently near each other, the differences of right-ascension and declination have been obtained by direct micrometer measurement. I have preferred this method to that of transits, and frequently when no catalogued star was near enough for direct measurement, I have selected some faint star for comparison and afterwards connected it with a catalogued star.

In making an observation the usual program has been as follows: Four settings were first made to determine the difference of declination, then eight settings to determine the difference of right-ascension, and finally, four more settings to determine the difference of declination. The two sets of declination measures have been combined to give a result corresponding to the epoch of the mean of the right-ascension settings. The incomplete observations were made at the time of connecting the comparison-stars, the times of transit of the planet having been recorded on the chronograph along with the transits of the stars.

The star places given are not definitive. I have been content to obtain their places from a single authority. The A.G. positions have been given wherever available.

From observations of August 15, September 27, and November 11, I obtained, last November, elements as follows (cf. *Astr. Nach.* No. 3537):

$$\begin{aligned}
\text{Epoch} &= \text{1898 August 31.5 Gr. M.T.} \\
M &= 221^\circ\ 33'\ 29''.10 \\
\omega &= 177\ 41\ 21.00 \\
\Omega &= 303\ 30\ 19.20 \\
i &= 10\ 49\ 33.50 \\
\varphi &= 12\ 52\ 16.10 \\
\log a &= 0.1637097 \\
\log e &= 9.3478354 \\
\mu &= 2015''.775 \\
\text{Period} &= 642.9290 \text{ days.}
\end{aligned}$$

A comparison of my observations made during 1898 with an ephemeris computed from these elements gives the following mean residuals:

Dates of Observation.	O—C $\Delta\alpha$ (s)	O—C $\Delta\delta$ (″)	No. of Obs.
September 6 to 12,	+0.08	+2.7	8, 7
18 to 28,	+0.04	+2.8	4
November 5 to 13,	−0.18	+2.7	6
December 9 to 12,	−0.03	+4.4	4
21 to 23,	−0.07	+2.2	3

The observations for 1899 have not been compared with the computed places except in isolated cases. Thus, we have, for

	$\Delta\alpha$ (s)	$\Delta\delta$ (″)
January 3,	+0.36	−0.1
May 4,	−0.05	−1.3

From these residuals it appears that the above elements closely represent the observed path of the planet during four-tenths of a complete revolution and that the corrections which they will require will be very small.

1898–9	Mt. Hamilton M.T.	*	No. Comp.	Planet – * $\Delta\alpha$	Planet – * $\Delta\delta$	Planet's apparent α	Planet's apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Sept. 6	9 30 12	1	12 , 8	+1 31.39	– 1 35.4	20 48 17.74	– 6 19 22.7	n8.436	0.781
	9 30 12	2	12	+2 6.39	. . .	20 48 47.86	. . . .	n8.436	. .
7	8 13 17	1	8 , 8	+0 26.04	– 1 51.1	20 47 42.39	– 6 19 38.4	n9.233	0.778
9	9 9 31	3	8 , 8	+0 12.64	– 4 57.4	20 45 29.34	– 6 20 10.5	n8.588	0.781
10	11 5 43	4	8 , 8	+0 7.74	– 0 18.6	20 44 23.98	– 6 20 26.6	9.308	0.776
11	9 2 49	6	8 , 8	+0 9.14	– 2 16.3	20 43 32.05	– 6 20 44.0	n8.510	0.782
12	11 40 20	5	8 , 8	–0 18.12	+ 2 40.5	20 42 31.95	– 6 20 54.3	9.450	0.770
	11 47 24	7	8 , 8	+0 7.55	+ 3 39.0	20 42 31.66	– 6 20 51.5	9.467	0.770
18	9 9 44	8	8 , 8	–0 10.87	– 2 29.1	20 38 22.40	– 6 21 27.2	8.687	0.782
23	8 28 45	9	9 , 8	+0 16.17	+ 0 44.5	20 36 19.94	– 6 20 35.5	7.971	0.782
27	8 31 54	9	8 , 8	–0 25.94	+ 2 36.5	20 35 37.78	– 6 18 43.6	8.696	0.789
28	7 48 43	9	8 , 8	–0 28.38	+ 3 14.1	20 35 35.32	– 6 18 6.0	n8.491	0.781
Nov. 5	9 3 52	10	8 , 8	–1 43.66	– 3 17.8	21 4 15.33	– 4 36 20.9	9.523	0.755
6	6 50 50	10	12 , 8	–0 27.90	+ 1 18.8	21 5 31.28	– 4 31 44.2	9.012	0.766
7	8 35 19	11	8 , 8	+0 7.62	+ 4 47.1	21 7 1.61	– 4 26 8.0	9.474	0.757
10	8 44 19	12	8 , 8	–0 1.77	+ 1 26.0	21 11 26.30	– 4 9 37.9	9.507	0.753
11	7 30 6	14	10 , 10	–0 19.29	+ 1 59.1	21 12 51.34	– 4 4 11.8	9.306	0.759
13	7 53 30	15	8 , 8	+0 9.39	– 1 22.3	21 15 57.79	– 3 52 9.4	9.554	0.756
Dec. 9	7 59 59	17	8 , 8	–0 18.20	– 0 34.7	22 3 11.80	– 0 26 26.6	9.541	0.728
10	6 45 56	18	8 , 8	+0 0.24	+ 4 1.3	22 5 5.71	– 0 17 20.7	9.369	0.727
11	7 42 52	19	8 , 8	+0 12.72	+ 5 4.8	22 7 13.80	– 0 7 9.1	9.517	0.726
12	7 24 24	21	8 , 8	+0 14.11	+ 3 44.9	22 9 16.91	+ 0 2 46.1	9.483	0.725
21	7 13 29	23	10 , 10	+0 17.60	+ 2 57.1	22 28 34.91	+ 1 38 5.0	9.494	0.712
22	7 0 33	25	8 , 8	+0 16.78	– 0 30.7	22 30 46.34	+ 1 49 31.2	9.470	0.710
23	7 30 39	27	8 , 8	–0 17.35	+ 1 5.2	22 33 1.84	+ 2 1 11.9	9.534	0.711
27	8 19 51	29	8 , 8	+0 9.89	+ 0 54.4	22 42 11.17	+ 2 48 10.8	9.612	0.711
1899 Jan. 3	8 13 31	31	10 , 8	+0 50.61	– 2 58.4	22 58 32.07	+ 4 13 54.8	9.618	0.704
5	6 45 0	32	8 , 8	–0 0.45	+ 3 27.2	23 3 10.72	+ 4 38 34.0	9.497	0.687
20	7 13 14	33	8 , 8	–0 9.65	+ 1 17.2	23 40 54.40	+ 8 0 36.0	9.578	0.670
23	6 54 3	35	8 , 8	–0 8.46	+ 2 35.8	23 48 46.56	+ 8 42 38.2	9.556	0.659
25	7 16 50	36	8 , 8	+0 1.65	+ 3 26.5	23 54 10.54	+ 9 11 22.2	9.593	0.583
27	7 20 28	38	8 , 8	–0 16.92	–10 0.7	23 59 34.47	+ 9 39 54.7	9.601	0.663
28	6 45 52	39	8 , 8	–0 25.39	– 1 13.6	0 2 13.71	+ 9 53 50.9	9.554	0.657
29	7 14 36	41	12 , 8	–1 2.48	+ 3 58.2	0 5 1.39	+10 8 31.1	9.597	0.658
30	7 14 14	42	8 , 8	+0 3.56	– 8 14.5	0 7 45.92	+10 22 53.3	9.599	0.656
Feb. 6	7 44 3	44	8 , 8	+0 17.28	– 8 42.1	0 27 30.54	+12 4 38.7	9.640	0.663
7	7 17 44	45	8 , 8	–0 32.74	– 2 57.1	0 30 19.71	+12 18 49.3	9.616	0.647
	7 32 59	46	8 , 8	+0 14.61	– 5 54.9	0 30 21.78	+12 19 7.8	9.632	0.656
8	8 1 35	48	8 , 8	+0 32.28	+ 2 45.3	0 33 19.11	+12 33 56.9	9.656	0.671
	8 24 34	49	8	+2 39.99	. . .	0 33 21.89	. . . .	9.668	. .
9	7 5 22	50	8 , 8	–0 6.73	– 0 36.0	0 36 5.78	+12 47 49.2	9.604	0.637
10	8 35 15	52	8 , 8	+0 9.42	– 1 1.7	0 39 12.36	+13 3 18.6	9.674	0.690
	8 54 53	53	10	+1 50.34	. . .	0 39 14.82	. . . .	9.679	. .
11	8 12 37	54	8 , 8	–0 1.99	– 3 16.7	0 42 5.08	+13 17 21.9	9.667	0.677
	8 58 22	55	8	–1 55.76	. . .	0 42 10.89	. . . .	9.680	. .
	8 58 22	56	8	+0 49.47	. . .	0 42 11.67	. . . .	9.680	. .
13	8 3 13	57	8 , 8	–0 15.05	– 2 11.8	0 48 0.19	+13 46 22.1	9.662	0.669
	8 25 19	59	8 , 8	+0 2.50	+ 4 15.6	0 48 3.21	+13 46 33.4	9.673	0.683
15	7 42 35	61	8 , 8	+0 11.48	+ 3 24.4	0 53 57.18	+14 14 53.1	9.650	0.653
16	8 10 57	62	8 , 8	–0 5.54	– 2 36.5	0 56 1.80	+14 29 31.0	9.669	0.672
20	7 28 27	64	8 , 8	+0 16.59	+ 0 8.1	1 9 11.65	+15 25 58.0	9.645	0.638
21	7 22 16	66	8 , 8	–0 9.03	– 2 41.9	1 12 16.60	+15 40 0.1	9.941	0.633
Mar. 5	8 10 31	68	8 , 8	–0 7.35	+ 0 21.1	1 51 1.51	+18 22 22.7	9.684	0.664
11	8 29 39	70	8 , 8	–0 12.67	+ 1 45.3	2 11 21.80	+19 36 53.3	9.693	0.678
Apr. 4	7 54 3	71	8 , 8	–0 22.79	– 3 32.6	3 38 44.50	+23 19 41.5	9.695	0.629
7	8 32 46	72	8 , 8	+0 14.02	+ 1 52.1	3 50 24.76	+23 36 44.4	9.707	0.673
10	8 11 54	74	8 , 8	+0 1.72	+ 0 35.1	4 2 1.87	+23 50 41.4	9.703	0.644
12	8 3 51	76	8 , 8	+0 13.27	+ 2 10.7	4 9 51.66	+23 58 17.3	9.664	0.560
14	8 9 50	77	8 , 8	–0 7.89	+ 0 23.3	4 17 45.48	+24 4 33.9	9.704	0.644
14	8 19 33	78	8 , 8	–0 8.35	+ 0 34.3	4 17 47.05	+24 4 34.1	9.706	0.656
19	8 29 15	79	8 , 8	–0 4.33	+ 1 49.0	4 37 40.01	+24 13 50.4	9.709	0.671
20	8 41 51	81	8 , 8	+0 21.58	+ 4 17.5	4 41 42.55	+24 14 42.5	9.709	0.642
May 4	8 7 56	82	8 , 8	–0 7.47	+ 3 41.4	5 37 56.04	+23 46 7.6	9.702	0.642
5	8 47 3	84	8 , 8	+0 3.67	+ 1 17.8	5 42 10.78	+23 41 11.5	9.707	0.687
9	8 16 29	86	8 , 8	+0 4.03	+ 1 38.1	5 58 4.21	+23 17 47.8	9.706	0.676

Mean Places for 1898.0 and 1899.0 of Comparison-Stars.

∗	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 47 12.00	+4.35	− 6 18 5.6	+18.3	DM. −6°5608, Ball, Vienna, Ottakring Zones
2	20 46 37.12	4.35	− 6 18 55.4	18.2	DM. −6°5605, " " " "
3	20 45 12.37	4.33	− 6 15 30.9	17.8	DM. −6°5600, " " " "
4	20 44 11.92	4.32	− 6 20 26.0	18.0	DM. −6°5596. Connected with ∗5
5	20 42 45.76	4.32	− 6 23 52.5	18.1	DM. −6°5588, Ball, Vienna, Ottakring Zones
6	20 43 18.59	4.32	− 6 18 15.8	18.1	DM. −6°5589, " " " "
7	20 42 19.80	4.31	− 6 24 48.2	17.7	DM. −6°5586, " " " "
8	20 38 29.06	4.21	− 6 19 15.8	17.7	DM. −6°5567, " " " "
9	20 35 59.60	4.17	− 6 21 37.7	17.7	DM. −6°5558, " " " "
10	21 5 55.33	3.66	− 4 33 22.9	19.8	Valentiner, Karlsruhe Zones
11	21 6 50.36	3.63	− 4 31 14.8	19.7	Connected with ∗10
12	21 11 24.48	3.59	− 4 11 23.9	20.0	Connected with ∗13
13	21 11 4.97	3.59	− 4 15 9.2	19.9	Schjellerup 8587
14	21 13 7.05	3.58	− 4 6 31.0	20.1	Valentiner, Karlsruhe Zones
15	21 15 44.84	3.56	− 3 51 7.4	20.3	Connected with ∗16
16	21 15 11.57	3.56	− 3 53 46.0	20.3	Schjellerup 8624
17	22 3 26.54	3.46	− 0 26 15.0	23.1	" 9032
18	22 5 1.94	3.47	− 0 21 45.1	23.1	Connected with ∗17
19	22 6 57.62	3.46	− 0 12 47.2	23.3	" " ∗20
20	22 8 6.39	3.46	− 0 15 43.6	23.3	Schjellerup 9074
21	22 8 59.33	3.47	− 0 1 22.2	23.4	10±M. Connected with ∗22
22	22 9 2.12	3.47	− 0 5 17.6	23.4	Copeland and Börgen, Göttingen Catal. 6142–3
23	22 28 13.80	3.51	+ 1 34 43.8	24.1	DM. +1°4624. Connected with ∗24
24	22 29 57.88	3.49	+ 1 34 2.5	24.3	Boss, Albany A.G. Catal. 7812
25	22 30 26.05	3.51	+ 1 49 37.6	24.3	11½M. Connected with ∗26
26	22 33 17.07	3.49	+ 1 46 10.4	24.5	Boss, Albany A.G. Catal. 7832
27	22 33 15.72	3.47	+ 1 59 42.2	24.5	10½M. Connected with ∗28
28	22 33 44.67	3.47	+ 1 59 34.4	24.5	DM. +1°4637. Bonn Beob. VI
29	22 41 57.79	3.49	+ 2 46 51.5	24.9	11½M. Connected with ∗30
30	22 44 16.69	3.50	+ 2 42 11.6	25.0	Boss, Albany A.G. Catal. 7889
31	22 57 41.02	0.44	+ 4 16 47.1	6.1	" " " 7951
32	23 3 10.72	0.45	+ 4 35 0.8	6.0	" " " 7984
33	23 41 3.53	0.52	+ 7 59 12.4	6.4	11½M. Connected with ∗34
34	23 39 21.78	0.51	+ 7 56 12.2	6.4	Glasgow 6282
35	23 48 54.47	0.55	+ 8 39 55.9	6.5	Rümker 11724
36	23 54 8.33	0.56	+ 9 7 49.4	6.6	11½M. Connected with ∗37
37	23 53 39.00	0.56	+ 8 59 21.8	6.6	Schur, Göttingen Catal. 6862
38	23 59 50.82	0.57	+ 9 49 48.7	6.7	Weisse-Bessel 23h1181
39	0 2 38.53	0.57	+ 9 54 57.8	6.7	11½M. Connected with ∗40
40	0 4 30.17	0.58	+ 9 57 14.6	6.7	Schur, Göttingen Catal. 16
41	0 6 3.29	0.58	+10 4 26.3	6.6	" " " 28
42	0 7 41.79	0.57	+10 31 1.2	6.6	Connected with ∗43
43	0 4 50.58	0.53	+10 35 1.3	6.6	Glasgow 21
44	0 27 12.65	0.61	+12 13 14.0	6.8	Bonn Beob. VI 66
45	0 30 51.82	0.63	+12 21 39.6	6.8	" " VI 61
46	0 30 6.55	0.62	+12 24 56.0	6.7	11½M. Connected with ∗47
47	0 26 27.90	0.62	+12 21 42.2	6.8	Schur, Göttingen Catal. 142
48	0 32 46.20	0.63	+12 31 4.8	6.8	11½M. Connected with ∗49
49	0 30 41.28	0.62	+12 39 25.4	6.8	Schur, Göttingen Catal. 170
50	0 36 11.87	0.64	+12 48 18.3	6.9	12M. Connected with ∗51
51	0 38 57.02	0.65	+12 45 16.8	6.9	Schur, Göttingen Catal. 219
52	0 39 2.31	0.63	+13 4 13.4	6.9	Connected with ∗53
53	0 37 23.85	0.63	+13 5 28.7	6.9	Schur, Göttingen Catal. 210
54	0 42 6.43	0.64	+13 20 31.9	6.7	10M. Connected with ∗55
55	0 44 6.00	0.65	+13 26 49.1	7.0	Weisse-Bessel 722
56	0 41 21.56	0.64	+13 27 6.5	6.9	Munich 11 227
57	0 48 14.59	0.65	+13 48 27.2	6.7	Connected with ∗58
58	0 47 51.65	0.64	+13 55 29.3	6.8	Schjellerup 307
59	0 48 0.07	0.64	+13 42 11.0	6.8	10M. Connected with ∗60
60	0 47 34.46	0.64	+13 36 1.8	6.8	Weisse-Bessel 790
61	0 53 45.05	0.65	+14 11 21.9	6.8	Munich2 298
62	0 57 6.65	0.69	+14 32 0.6	6.9	12M. Connected with ∗63
63	0 58 46.77	+0.70	+14 41 7.2	+ 6.9	Weisse-Bessel 989

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
64	1 8 54.37	+0.69	+15 25 43.1	+ 6.8	DM. +15°178. Connected with *65
65	1 8 45.70	0.69	+15 35 57.5	6.8	Auwers, Berlin A.G. Catal. 347
66	1 12 25.21	0.72	+15 42 35.1	6.9	10ᴹ. Connected with *67
67	1 10 52.90	0.71	+15 38 3.5	6.9	Auwers, Berlin A.G. Catal. 356
68	1 51 8.09	0.77	+18 21 54.9	6.7	11ᴹ. Connected with *69
69	1 51 59.98	0.77	+18 29 55.9	6.7	Auwers, Berlin A.G. Catal. 560
70	2 11 33.66	0.81	+19 35 1.4	6.6	" " " 635
71	3 39 6.27	1.02	+23 23 8.7	5.2	Becker, " " 1127
72	3 50 9.70	1.04	+23 34 47.3	5.0	11ᴹ. Connected with *73
73	3 49 47.26	1.03	+23 31 58.0	5.0	Becker, Berlin A.G. Catal. 1249
74	4 1 59.10	1.05	+23 50 1.7	4.6	10ᴹ. Connected with *75
75	4 3 40.61	1.04	+23 48 24.1	4.6	Becker, Berlin A.G. Catal. 1341
76	4 9 37.32	1.07	+23 56 2.3	4.3	Bonn Beob. VI 656
77	4 17 52.27	1.10	+24 4 6.5	4.1	Becker, Berlin A.G. Catal. 1416
78	4 17 54.30	1.10	+24 3 56.8	4.0	" " " 1417
79	4 37 43.18	1.16	+24 11 57.9	3.5	13ᴹ. Connected with *80
80	4 39 10.26	1.16	+24 13 23.6	3.5	Becker, Berlin A.G. Catal. 1512
81	4 41 19.81	1.16	+24 10 21.3	3.5	DM. +24°686. Connected with *80
82	5 38 2.21	1.30	+23 42 24.9	1.3	12½ᴹ. Connected with *83
83	5 39 49.04	1.30	+23 42 22.4	1.2	Becker. Berlin A.G. Catal. 1934
84	5 42 5.90	1.30	+23 39 52.6	1.1	9½ᴹ. Connected with *85
85	5 42 10.42	1.30	+23 37 40.2	1.1	DM. +23°1055, Bonn. Beob. VI
86	5 57 58.86	+1.32	+23 16 9.2	+ 0.5	Becker, Berlin A.G. Catal. 2151

The observations of the following dates were made with the 36-inch telescope: Sept. 7; Nov. 10; Jan. 5, 20; Feb. 9, 10, 16; Apr. 7, 14, 19, 20; May 4, 5, 9. The observations of Sept. 6; Nov. 5, 6; Jan. 3, 29 were made by transits. Stars 12, 21, 27, 36, 57, 59, 64, 72 and 84 were connected by direct micrometer-measurements; 50, 52, 62, 74, 79 and 82 by transits by eye-and-ear method; the other connections were made chronographically. For stars 55 and 56, I obtain a difference of right-ascension equal to $2^m\,45^s.14$; the DM. difference is $2^m\,43^s.8$. At the last observation I estimated the magnitude of the planet at 13½.

Mt. Hamilton, Cal., 1899 *May* 9.

COMET *d* 1899 = 1892 III.

A dispatch from Prof. Keeler to the Harvard College Observatory states that Holmes's Comet, 1892 III, was found by Perrine in the position,

Gr. M.T.	α	δ
1899 June 10.9644	$1^h\,15^m\,31^s.6$	+17° 29′ 39″

It is noted as faint.

By Zweirs's ephemeris, *A.N.* 3553, the above place gives as the time of perihelion passage 1899 April 28.083, approximately. This gives the following

Ephemeris for Greenwich Mean Noon.

1899	α	δ	Br.
	h m s	° ′	
June 11.0	1 15 36	+17 30	1.00
13.0	1 18 56	+18 7	
June 15.0	1 22 15	+18 43	1.02
17.0	25 33	19 19	
19.0	28 50	19 55	1.04
21.0	32 6	20 31	
23.0	35 21	21 7	1.06
25.0	38 34	21 42	
27.0	41 47	22 18	1.08
29.0	44 58	22 53	
July 1.0	48 7	23 28	1.11
3.0	51 16	24 3	
5.0	54 22	24 38	1.13
7.0	1 57 26	25 13	
9.0	2 0 26	25 48	1.16
11.0	2 3 24	+26 22	

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SECULAR PERTURBATIONS OF *VENUS* BY ACTION OF *URANUS*,

BY ERIC DOOLITTLE.

The elements employed in the following computation are from Dr. G. W. HILL's *"New Theory of Jupiter and Saturn,"* pages 192, 554 and 109:

Venus.	*Uranus.*
$\pi = 129°\ 27'\ 42''.83$	$\pi' = 168°\ 15'\ 6''.7$
$i = 3\ 23\ 35.01$	$i' = 0\ 46\ 20.54$
$\Omega = 75\ 19\ 53.08$	$\Omega' = 73\ 14\ 8.0$
$e = 0.00684311$	$e' = 0.0469236$
$n = 2106641''.357$	$n' = 15425''.752$
$\log a = 9.8593378$	$\log a' = 1.2831044$
$m = \frac{1}{408.124}$	$m' = \frac{1}{22.800}$

Epoch 1850.0 Gr. M.T.

The value of m' is that suggested recently by Dr. HILL (*Astronomical Journal*, No. 316).

The work was carried twice through from the beginning, and such test equations as were known were applied.* An inspection of the final sums renders it evident that the computation is here extended to an unnecessary accuracy, since the results obtained from but six points of division are practically identical with those from twelve. But if it is desired to test the work as the computation proceeds, by comparing the sums of the functions corresponding to the odd and even points of division respectively, it becomes necessary to employ at least eight points of division, and in this case the results may be regarded as furnishing two determinations of the perturbations, one from the even, and one from the odd points of division. It may be remarked that the final values of the differential coefficients are here written to so many significant figures, to indicate with what accuracy the numerical work has been performed.

The values of the preliminary constants and of the principal auxiliaries are as follows:

$I = 2°\ 37'\ 16''.883$	$\log k = 9.9995460$
$II = 233\ 30\ 46.37$	$\log k' = 9.9999992$
$II' = 272\ 18\ 13.25$	$\log c = 9.9089914$
$K = 321\ 12\ 24.44$	$c = 0.81091500$
$K' = 324\ 12\ 41.79$	

E	log r	v	A	ϵ	log B	g	h
0°	9.8563557	0° 0′ 0″.00	369.8294733	242° 53′ 5″.66	1.4670856	60.35594	367.496220
30	9.8567564	30 11 47.87	370.1021929	356 11 19.695	1.4910939	3.43885	367.496155
60	9.8578493	60 20 24.50	370.0319613	9 33 40.95	1.4851641	20.89679	367.496140
90	9.8593378	90 23 31.50	369.6376057	22 45 57.14	1.4184580	95.77536	367.496165
120	9.8608213	120 20 20.31	369.0247981	35 27 12.22	1.3752483	153.60480	367.496245
150	9.8619040	150 11 43.65	368.3577351	46 48 25.02	1.2507254	136.75991	367.496230
180	9.8622996	180 0 0.00	367.8151465	53 48 16.22	1.0349310	62.03086	367.496275
210	9.8619040	209 48 16.35	367.5424142	31 51 52.13	0.6155264	3.84740	367.496245
240	9.8608213	239 39 39.69	367.6126214	310 48 29.84	0.8162133	19.92946	367.496135
270	9.8593378	269 36 28.50	368.0069649	308 24 14.81	1.1372326	93.69138	367.496165
300	9.8578493	299 39 35.50	368.6197847	317 52 42.11	1.3084068	150.96247	367.496240
330	9.8567564	329 48 42.13	369.2868724	329 55 49.79	1.4096084	134.26735	367.496240
Σ_1	9.1559965	900 00 00.00	2212.9337853	970 23 27.30	7.4870491	467.78032	2204.977255
Σ_2	9.1559964	1080 00 00.00	2212.9337852	1095 57 38.58	7.3526447	467.78025	2204.977200

* In the duplication, the following slight error was found in ZECH's "*Tafeln der Additions und Subtractions-Logarithmen,*" second edition, page 782; 0.9786992 should be 0.9786996.

E	l	G	G'	G''	θ	log $\mathfrak{K}$	log $\mathfrak{L}'$	log $\mathfrak{N}$
0°	+1.522310	367.495771	1.6238940	0.1011370	3° 55′ 40.″93	0.00153256	0.27504417	0.17838936
30	+1.795095	367.496129	1.8003166	0.0051977	4 1 9.46	0.00160469	0.27514027	0.17849746
60	+1.724880	367.495985	1.7573874	0.0323564	4 0 5.50	0.00159052	0.27512139	0.17847622
90	+1.330495	367.495453	1.5014398	0.1732316	3 52 23.80	0.00149009	0.27498757	0.17832569
120	+0.717605	367.495105	1.0990547	0.3803068	3 38 8.91	0.00131281	0.27475131	0.17805993
150	+0.050560	367.495217	0.6363646	0.5847917	3 18 7.21	0.00108264	0.27444453	0.17771485
180	−0.492075	367.495816	0.2329563	0.7245710	2 55 22.89	0.00084825	0.27413211	0.17736340
210	−0.764775	367.496217	0.0134531	0.7782012	2 39 26.72	0.00070103	0.27393587	0.17714264
240	−0.691455	367.495988	0.0708724	0.7651843	2 43 51.72	0.00074042	0.27398839	0.17720173
270	−0.300145	367.495472	0.3769271	0.6763791	3 3 57.85	0.00093336	0.27424555	0.17749102
300	+0.312600	367.495121	0.8167025	0.5029833	3 25 59.41	0.00117044	0.27456155	0.17784648
330	+0.979685	367.495243	1.2686692	0.2879853	3 43 48.64	0.00128191	0.27484340	0.17816353
Σ_1	+3.090865	2204.973786	5.6008673	2.5065388	20 39 9.36	0.00719500	1.64759892	1.06733712
Σ_2	+3.090915	2204.973731	5.6001704	2.5057866	20 38 53.68	0.00719372	1.64759719	1.06733519

E	log N	log P	log Q	log V	J'_1	J_2	J_3	F_2
0°	5.7255240	0.8698244	3.3385414	3.3383922	367.09942052	−0.77238411	−13.377206	+148.77538
30	5.7265669	0.8711894	3.3398056	3.3397979	366.74089875	−0.18040606	−16.560521	+ 35.51232
60	5.7286906	0.8732303	3.3418759	3.3418282	366.88453611	+0.52246333	−15.273725	− 87.54088
90	5.7313185	0 8753928	3.3441876	3.3439318	367.40160988	+0.87586900	− 9.861620	−187.41225
120	5.7337420	0.8770917	3.3461011	3.3455398	367.86665960	+0.72768333	− 1.774376	−237.34142
150	5.7353151	0.8778752	3.3470878	3.3462248	367.95568703	+0.32642368	+ 6.821041	−223.94969
180	5.7356234	0.8775397	3.3468788	3.3458097	367.72285452	+0.04295564	+13.621489	−150.82559
210	5.7345895	0.8761824	3.3455607	3.3444123	367.51508313	+0.01342241	+16.804806	− 37.56251
240	5.7324870	0.8741636	3.3435327	3.3424036	367.61069788	+0.04551264	+15.518012	+ 85.49071
270	5.7298710	0.8720154	3.3413115	3.3403134	367.89469814	−0.13535069	+10.105905	+185.36209
300	5.7274385	0.8703090	3.3394394	3.3386972	367.98729038	−0.54951786	+ 2.018660	+235.29114
330	5.7258446	0.8695041	3.3384162	3.3379911	367.66272932	−0.88324571	− 6.576756	+221.89949
Σ_1	4.3835055	5.2421587	0.0563693	0,0526707	*2202.66492021	+0.01671297	+ 0.732854	− 6.15066
Σ_2	4.3835056	5.2421592	0.0563694	0.0526713	*2202.66491965	+0.01671263	+ 0.732855	− 6.15055

* The term in G'' has been removed in forming the sums.

E	F_3	$1000x\,R_0$	$1000000x\,S_0$	$1000x\,W_0$	$1000x\,\frac{1}{a}$ sin E$\cdot R^{(n)}$	$1000000x\,\frac{1}{a}\,S^{(n)}$
0°	− 4.0226412	0.02650922	−0.05811066	−0.002918780	+0.00000000	−0.08089097
30	− 0.1770896	0.02652281	−0.01305234	−0.003621493	+0.01844306	−0.01815231
60	− 1.6152186	0.02667654	+0.04940526	−0.003356828	+0.03204873	+0.06853681
90	− 6.9332675	0.02691093	+0.05269544	−0.002182313	+0.03720412	+0.07285096
120	−10.8407275	0.02710189	−0.01759673	−0.000401343	+0.03233767	−0.02424436
150	− 9.4434565	0.02715609	−0.09660941	+0.001506695	+0.01866093	−0.13277471
180	− 4.1342719	0.02707758	−0.10424233	+0.003017072	0.00000000	−0.14313458
210	− 0.2013093	0.02694790	−0.02527822	+0.003713882	−0.01851786	−0.03474102
240	− 1.5455370	0.02684358	+0.07399797	+0.003412656	−0.03204946	+0.10195266
270	− 6.7883563	0.02677475	+0.10841711	+0.002207472	−0.03701585	+0.14988562
300	−10.6594103	0.02669990	+0.05468656	+0.000432404	−0.03207678	+0.07586323
330	− 9.2743255	0.02659629	−0.02803268	−0.001439065	−0.01849416	−0.03898596
Σ_1	−32.8178065	0.16090871	−0.00185993	+0.000185181	+0.00028016	−0.00191721
Σ_2	−32.8178047	0.16090877	−0.00186010	+0.000185178	+0.00028024	−0.00191742

E	$1000\,x \{ R_0 \sin v + (\cos v + \cos E)\, S_0 \}$	$1000\,x \{ -R_0 \cos v + \left(\frac{r}{a} \sec^2 \varphi + 1 \right) \sin v \,.\, S_0 \}$	$1000x\, W_0 \sin u$	$1000x\, W_0 \cos u$	$1000\,x\, \frac{2}{a}\, r\, R_0$
0°	−0.000 11622	−0.026 50922	−0.002 365 243	−0.001 710 234	0.052 65561
30	+0.013 31757	−0.022 93687	−0.003 603 757	−0.000 357 980	0.052 73125
60	+0.023 23048	−0.013 11517	−0.003 055 297	+0.001 390 488	0.053 17953
90	+0.026 90995	+0.000 28955	−0.001 266 575	+0.001 777 154	0.053 82187
120	+0.023 40803	+0.013 65911	−0.000 038 680	+0.000 399 475	0.054 38924
150	+0.013 66523	+0.023 46772	−0.000 620 648	−0.001 372 927	0.054 63405
180	+0.000 20848	+0.027 07758	−0.002 444 894	−0.001 767 867	0.054 52574
210	−0.013 35043	+0.023 40859	−0.003 693 094	−0.000 392 395	0.054 21519
240	−0.023 24178	+0.013 43111	−0.003 122 646	+0.001 376 698	0.053 87086
270	−0.026 77488	−0.000 03361	−0.001 305 659	+0.001 779 939	0.053 54950
300	−0.023 14722	−0.013 30732	−0.000 046 772	+0.000 429 867	0.053 21706
330	−0.013 42562	−0.022 95918	−0.000 583 802	−0.001 315 326	0.052 87735
Σ_1	+0.000 34177	+0.001 23615	−0.011 073 532	+0.000 118 427	0.321 82904
Σ_2	+0.000 34182	+0.001 23620	−0.011 073 535	+0.000 118 465	0.321 82921

The equation $\sin q \,.\, \frac{1}{2} A_1^{(s)} + \cos q \,.\, B_0^{(c)} = 0$ is found to give the residual $+0.000\,000\,000\,000\,000\,020$.

The values of the differential coefficients are as follows:

$$\left[\frac{de}{dt}\right]_{00} = +\; 0.''120\,00343\; m' \qquad p9.079\,1936$$

$$\left[\frac{d\chi}{dt}\right]_{00} = +\; 63.424\,159\; m' \qquad p1.802\,2547$$

$$\left[\frac{di}{dt}\right]_{00} = +\; 0.041\,58807\, m' \qquad p8.618\,9687$$

$$\left[\frac{d\Omega}{dt}\right]_{00} = -\; 65.693\,091\; m' \qquad n1.817\,5197$$

$$\left[\frac{d\pi}{dt}\right]_{00} = +\; 63.308\,999\; m' \qquad p1.801\,4655$$

$$\left[\frac{dL}{dt}\right]_{00} = -113.109\,825\; m' \qquad n2.053\,5003$$

By substituting the above value for m' there finally results:

$$\left[\frac{de}{dt}\right]_{00} = +0.''000\,005\,263\,308 \qquad \left[\frac{d\Omega}{dt}\right]_{00} = -0.''002\,881\,2762$$

$$\left[\frac{d\chi}{dt}\right]_{00} = +0.002\,781\,7616 \qquad \left[\frac{d\pi}{dt}\right]_{00} = +0.002\,776\,7109$$

$$\left[\frac{di}{dt}\right]_{00} = +0.000\,001\,821\,038 \qquad \left[\frac{dL}{dt}\right]_{00} = -0.004\,960\,9570$$

The comparison with the results of LeVerrier and Newcomb is as follows:

	Results of LeVerrier	Results of Newcomb	Method of Gauss
$\left[\frac{de}{dt}\right]_{00} =$	0.''000 00	+0.''000 01	+0.''000 0053
$e\left[\frac{d\pi}{dt}\right]_{00} =$	+0.000 02	+0.000 02	+0.000 0190
$\left[\frac{di}{dt}\right]_{00} =$	+0.000 002	0.000 00	+0.000 0018
$\sin i\left[\frac{d\Omega}{dt}\right]_{00} =$	−0.000 165	−0.000 17	−0.000 1705

The Flower Observatory, 1899 *May* 23.

DYNAMICS OF A NEBULA,

By Dr. E. J. Wilczynski.

In a former paper I have given a general outline of a theory of the nebulas, special attention being given to those of a special structure. (1) I believe that the subject is of sufficient interest to warrant a second and more explicit account, especially as it appears very desirable to have some of the photographs now at the disposal of astronomers, discussed from this standpoint.

It is quite unessential whether we regard a nebula as an assemblage of meteors, or as a gaseous mass obeying the laws of hydrodynamics. The results, as discussed below, will remain qualitatively unaltered if one hypothesis be substituted for the other. and in a great many of them there will be even no quantitative changes. For convenience and clearness it therefore appears best to consider the nebula as a swarm of meteors.

Suppose that in some way, which we do not propose to discuss, it has come about that every particle describes more or less approximately a circular orbit around the center of gravity. There may or may not be a condensation at the center. and there may or may not be secondary condensations at different points of the mass. Now such a condensation is by no means necessarily stable. If, to

(1) *Astrophysical Journal*, August, 1896.

take a simple case, we consider a spherical swarm of meteors the mass of each being equal to m, and their mean distance being 2d; if, moreover, M is the mass of a central body, and R is the distance of the swarm's center of gravity from the central body, then if

$$\frac{2M}{R^3} > \frac{m}{d^3}$$

the swarm will be dissolved. (1) The mutual attraction of the particles is not great enough to withstand the dissolving influence of the central force. A more exact limit is given by

$$\frac{3M}{R^3} > \frac{m}{d^3}$$

which is due to M. CHARLIER and M. PICARD. (2)

If the condition of stability is fulfilled, *i.e.* if $\frac{3M}{R^3} < \frac{m}{d^3}$ it is reasonable to suppose that the future of the system is essentially such as is usually given by writers on cosmogony. The secondary body will gradually contract, and finally become a star, single or double according to circumstances.

If, however, $\frac{3M}{R^3} > \frac{m}{d^3}$ the spherical swarm is unstable, and it is well worth while to investigate what will then happen. Of course, very likely, such an unstable spherical cluster of meteors could never have been formed, for the forces which tend towards its destruction would prevent its formation in the first place. Nevertheless we will be justified in studying the problem, for the facts thus brought out will be qualitatively so general as to admit of the widest application. Moreover, in every problem of mechanics certain initial conditions must be postulated, and especially is this true in cosmogony.

As the central attraction, or rather its differential effect, is the influence which causes the dissolution of the globular mass, we will now regard it as the only force working upon it. We will therefore neglect the mutual attraction of the particles itself. This is of course a rough method, but is justified in so far as the dissolution can only take place when the mass is small, and moreover as the mass is becoming more and more disintegrated the mutual attraction of the particles becomes smaller and smaller.

Let O be the center of attraction, and A and B two small masses of the cluster. In the beginning, for $t = o$, let us suppose that O, A and B lie upon a straight line. Let $\overline{OA} < \overline{OB}$. Then according to KEPLER's third law, if ω_1, ω_2, T_1, T_2, be respectively the angular velocities and periodic times of A and B, so that

$$\omega_1 = \frac{2\pi}{T_1} \qquad \omega_2 = \frac{2\pi}{T_2}$$

we have

$$\frac{T_1^2}{T_2^2} = \frac{a^3}{b^3}$$

a and b being equal to the distances OA and OB respectively. Therefore

$$\frac{\omega_1}{\omega_2} = \frac{T_2}{T_1} = \left(\frac{b}{a}\right)^{\frac{3}{2}}$$

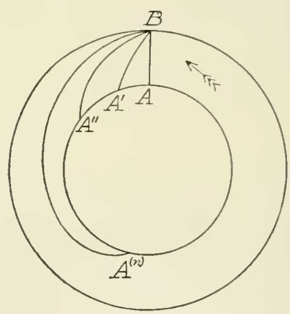
Let ω, and T be the same quantities for a point P intermediate between A and B, say at a distance r from O. Then

$$\omega = \omega_1 \frac{a^{\frac{3}{2}}}{r^{\frac{3}{2}}}$$

For $t = o$, O, A and P were upon a straight line. Let φ be the angle which the radius-vector of P makes with this line at the time t. Then

$$\varphi = \omega_1 \frac{a^{\frac{3}{2}}}{r^{\frac{3}{2}}} t$$

At a given moment t = const., this represents a spiral, *i.e.*, the straight line AB has changed into a spiral, which goes on changing all the time. This is quite clear directly. For the point A completes its orbital motion in less time than B, so that when B has made a complete revolution A will have made more than the revolution, and will have advanced to A'. Thus, after one revolution of B, the straight line AB is changed into the curve $A'B$, after two revolutions into $A''B$, etc., the spiral form being evident.



This is our explanation of spiral nebulas. They are not then to be regarded as their appearance would seem to suggest as a sort of whirlpool. The motion of the particles composing them is not upon the spiral curves seen in the telescope, but in accordance with the law of gravity in curves more or less approaching conic sections, if the dis-

(1) SCHIAPARELLI. *Entwurf einer astronomischen Theorie der Sternschnuppen.* Translation by BOGUSLAWSKI.

(2) cf. TISSERAND. *Mécanique Céleste*, T. IV.

turbing forces are not too great. Of course the formulas we have quoted are only very coarse approximations, but it is essential to note that qualitatively the result will always hold, excepting only the case that all particles in the meteoric swarm rotate with the same angular velocity. This is obviously an exceptional case, and moreover one in which there would be no dissolution. The swarm would rotate as the moon about the earth. The great advantage which we claim for our theory is that it shows how spiral nebulas may be formed, without invoking anything more complicated or mysterious than the law of gravitation.

As the nebula grows older, the coils of the spiral will multiply in number. Thus a spiral nebula must be considered old or young, according to the number of its coils. Let the points A and B in our example be the points nearest and most distant from the center of such a spiral, and let q_a and q_b denote the values of q for $r = a$ and $r = b$, respectively, at the time t. Suppose that $q_a = q_b + n2\pi$ where n is any positive quantity. Then

$$\omega_1 t = \omega_2 t + n2\pi = \omega_1 \frac{a^{\frac{3}{2}}}{b^{\frac{3}{2}}} t + n2\pi$$

whence

$$t = \frac{2n\pi}{\omega_1} \frac{1}{1-\left(\frac{a}{b}\right)^{\frac{3}{2}}}$$

Now n denotes the number of coils and fractions of a coil, and may be found from a photograph of the nebula. $\frac{a}{b}$ can also be found more or less accurately. If ω_1 were known we could therefore compute the time which has elapsed since the beginning of the disintegration. Now, theoretically ω_1 can be determined by comparing observations made at two different times. It is perhaps not impossible that in some nebulas such motion may become perceptible in fifty years or a century. *If this be so, our formula enables us to find approximately the length of the spiral stage of development for those nebulas.*

It is easy to see from our point of view that the spiral nebula is only a form of transition. As the nebula grows older, the coils of the spiral multiply, and approach each other. Finally, they will mingle, since they have a finite breadth, and either a planetary or a ring nebula will result. The nebula will be planetary if the original mass, which we supposed to be included between the circles of radius a and b, extended all the way towards the center of gravity. It will be annular if the radius a of the inner circle is not zero. At the center of gravity there may or may not be a condensation. May it also be suggested that *Saturn's* ring was formed in this way. It does not appear possible, if our theory is correct, that any of the matter in such a planetary or annular nebula could ever be formed into a satellite revolving about the center of gravity of the system, be this occupied by a central star or not. For any such body would appear to be unstable. The only change which an annular or planetary nebula probably undergoes would seem to be its gradual contraction, and associated with that, perhaps, some of the fundamental features of LAPLACE's hypothesis.

If the nebula be regarded as composed of fluid (gaseous, for instance), the following relation is fundamental for a planetary or ring nebula whose particles describe circular orbits:

$$f\frac{\partial V}{\partial r} - \frac{1}{\rho}\frac{\partial p}{dr} = -\omega^2 r$$

where V is the potential, ρ the density, p the pressure, ω the angular velocity of a point at the distance r from the axis of rotation, and f denotes a constant depending upon the units. In particular, if the fluid be a gas of the same temperature and composition throughout, $p = c\rho$, where c is known if the nature of the gas has been ascertained by the spectroscope. If ρ were known, we would thus obtain ω as function of r. The law according to which ρ values from point to point, even if not the absolute values of ρ in known units, may perhaps be found from photometric measures of different parts of the nebula, or from photographs, if certain assumptions are made. Thus ω as function of r, or the law of rotation, would be obtained.

University of California, Berkeley, Cal., 1899 Feb. 25.

MAXIMA AND MINIMA OF LONG-PERIOD VARIABLES,

BY J. A. PARKHURST.

The following observations, with the exceptions noted, were made with the 6.2-inch Brashear reflector. Those of 5798 *RU Herculis* and Mrs. FLEMING's variable in *Cassiopea* were made in part with the 12-inch Brashear refractor of the Yerkes Observatory, but in both cases the uncertainty arising from other causes exceeds that introduced by the change of instruments.

103. *T Andromedae.*

A series of 14 observations between 1897 Oct. 14 and 1898 Mar. 13 gives a maximum at $7^M.6$ about the middle of December; the following series of 12 observations between 1898 Aug. 29 and 1899 Feb. 28 gives as the date of maximum Oct. 18 ± 10 days, at $8^M.2$. In each case the scarcity of comparisons near maximum makes it impossible to fix

the date more exactly. At the last observation the star was $12^M.3$.

678. *U Persei.*

A single observation 1898 Aug. 30 found the star near maximum; a series of 15 between Nov. 2 and 1899 May 10 gave a well determined minimum at $12^M.0$, Feb. 18. At the last comparison the magnitude was 8.0.

2376. *S Lyncis.*

Following the maximum reported in *A.J.* 458 this star was below $12^M.2$ and indistinguishable from its close $12^M.5$ companion from 1899 Jan. 11 to Apr. 4. It then rose steadily to $10^M.8$ by May 29. A comparison with the 1898 curve suggests a minimum about 13^M early in March. The intervals between the ascending branches of the two curves average 295 days, in close agreement with the approximate period 293 days, suggested in *A.J.* 458.

2401. *X Geminorum.*

I have 18 observations between 1898 Nov. 14 and 1899 May 29. The star rose steadily from $11^M.5$ to a well marked maximum, $8^M.0$, 1899 Apr. 9; then fell nearly as rapidly to $9^M.6$ at the last comparison. At maximum it was $0^M.1$ fainter than DM. +30°1332 and equal to +29°1342, whose magnitudes according to the Harvard Meridian Photometer Catalogue are $8^M.01$ and $8^M.16$ respectively.

2815. *U Geminorum.*

In the following observations the magnitudes are expressed in Baxendell's scale; the times are Greenwich.

1899 May	1.63	$13^M.8$
	6.58	9.9
	8.62	10.7

The maximum evidently occurred not far from May 5.

5601. *S Ursae minoris.*

Since the maximum reported in *A.J.* 458 I have 17 observations ending 1899 May 29. The star fell steadily to a minimum at $11^M.6$, 1899 Mar. 10, and rose to $8^M.9$ at the last comparison. My four observed maxima since 1896 Jan. 24 give a period of 318 days, the four minima give 329 days. The difference seems to be partly due to the flatness of the curve both at maximum and minimum, rendering the exact dates somewhat uncertain.

5798. *RU Herculis.*

This star has been followed continuously since the maximum, 1898 Mar. 13, reported in *A.J.* 441. It faded slowly, reaching the limit of the 6.2-inch 1898 Oct. 5. It remained below the limit till 1899 Jan. 10, then rose more rapidly to $9^M.0$ May 29. The curve suggests a minimum at about $13^M.5$ not far from 1898 Nov. 9, with an uncertainty of 15 or 20 days. The intervals between the ascending branches of the last two curves average 445 days. I have 32 observations between the above dates; 6, in June–Aug., 1898, being made with the 12-inch Yerkes refractor.

6100. *RV Herculis.*

After the maximum reported in *A.J.* 456 this star was last seen at $12^M.2$, low in the west 1898 Nov. 19. It was next seen after the minimum at $10^M.9$, 1899 Feb. 15. A comparison with the 1898 curve suggests a minimum within 10 or 15 days of 1899 Jan. 1. The 12 succeeding observations fix the maximum at 1899 Apr. 6, at $8^M.9$; May 29 it had fallen to $11^M.2$.

6549. *W Lyrae.*

I have 17 observations between the maximum reported in *A.J.* 458 and 1899 May 29. The star passed a minimum at $12^M.0$, 1899 Feb. 12, which date may be in error by a week; and had risen to $7^M.5$ at the last comparison.

7085. *RT Cygni.*

Since the minimum noted in *A.J.* 458 I have 10 observations ending 1899 May 28. The maximum was passed 1899 Feb. 14 (possibly 10 days earlier) at $6^M.7$, and at the last comparison the magnitude was 11.0.

Anderson's *Variable in Aquila.*

The discovery was announced in *A.N.* 3520, and a DM. observation, 1855 Sept. 7, $9^M.5$, was given in No. 3521. I have 25 observations between 1898 Oct. 8 and 1899 May 29. When first seen it was $11^M.6$ and fell slowly to $12^M.6$ when last seen in the evening. Dec. 17. It was first seen in the morning 1899 Feb. 15 at $11^M.2$ rising. It passed a well defined maximum 1899 Apr. 14, at $7^M.9$, and had fallen to $9^M.9$ at the last date mentioned. An inspection of the curve suggests a minimum about Jan. 1, not far from 13^M. The position of the variable was determined from DM. +12°4255 to be

R.A. $20^h\ 5^m\ 56^s$	Decl. +12° 33′.8	(1855)
8 3	41.7	(1900)

There is a $12^M.7$ star 0′.6 north, and a $12^M.2$, $0^s.5$ foll., 2′.0 north.

Anderson's *Variable in Pegasus.*

R.A. $21^h\ 14^m\ 8^s$	Decl. +30° 50′.3	(1855)
16 15	14 1.6	(1900)

After the minimum reported in *A.J.* 457 this star rose steadily to a maximum, about $8^M.7$. not far from 1899 Feb. 25. I have no observations between Jan. 28 and March 19, while it was hidden in the sun's rays, so that the maximum cannot be accurately determined. However, both branches of the light curve outside these limits are well covered by 14 observations, so that the uncertainty in time will not exceed 10 days. On May 10 the star had fallen to $11^M.8$. Compared with Rev. Mr. Anderson's observations in *A.N.* 3521, the period seems to be about 204 days.

7792. *SS Cygni.*

Since the report in *A.J.* 458 I have observed the following, in which T represents the time of passing $9^M.35$ on the rise.

Epoch	T	Max.
6, short	1899 Mar. 7.6	Mar. 9
6, long	May 1.8	May 5

The corrections to the elements given in *A.J.* 458 are -3.3 and -5.7 days, respectively.

Mrs. Fleming's *Variable in Cassiopea.*

R.A. $23^h\ 55^m\ 53^s$, Dec. $+54°\ 52'.3$, (1855)

The discovery of this variable was announced in Harvard College Observatory Circular No. 24 (*Astroph. Jour.* VII, 208). I have 38 observations between 1898 Feb. 15 and 1899 June 7. When first seen it was $9^M.8$. Early in March, 1898, it seemed a little brighter, about $9^M.6$, but I am not certain of a rise. After March it faded slowly till Sept. 7, when it passed below $12^M.8$, the limit of the 6.2-inch reflector. It was next seen after the minimum Dec. 10 at $12^M.8$. It then rose steadily to a maximum, $9^M.1$, 1899 April 8, and fell to $10^M.5$ at the last comparison. The curve suggests a minimum, about $13^M.2$, within 10 days of 1898 Oct. 26. A comparison of the descending branches of the two curves observed gives 434 days as the first approximation to the period. Five observations in 1898 June–Aug. were made with the 12-inch Yerkes refractor.

Marengo, Ill., 1899 *June* 22.

MICROMETRICAL OBSERVATIONS OF THE SATELLITE OF *NEPTUNE*,

By WILLIAM J. HUSSEY.

The following measures of the position-angle and distance of the satellite of *Neptune* were obtained with the 36-inch refractor of the Lick Observatory, using an eye-piece magnifying 520 diameters. In making an observation the following order was pursued. Six settings were made for determining the position-angle. The micrometer box was then rotated until the circle-reading differed 90° from the mean of the settings just obtained. The distance-measures were then made, and in some cases these were followed by a second determination of the position-angle.

Distances.

1898 Mt. Hamilton M.T.	Dist.	1898–9 Mt. Hamilton M.T.	Dist.
	°	h m s	°
Oct. 27 13 24 55 (h m s)	16.69	Dec. 23 9 1 8	13.28
28 13 18 52	12.77	Jan. 5 7 58 39	13.01
Nov. 17 12 19 16	16.19	12 8 5 9	16.80
Dec. 7 7 55 38	15.32	20 8 21 25	15.40
15 15 38 18	12.88	Feb. 10 11 3 55	16.93
16 8 33 43	17.12	16 10 23 43	16.75

Position-Angles.

1898 Mt. Hamilton M.T.	P.A.	1898–9 Mt. Hamilton M.T.	P.A.
Oct. 27 13 16 30 (h m s)	79.2	Dec. 16 8 23 43 (h m s)	264.2
28 13 10 34	33.3	23 8 53 10	211.5
28 13 27 57	31.7	Jan. 5 7 52 28	111.6
Nov. 17 12 13 20	242.3	12 7 57 5	62.8
17 12 27 39	242.8	20 8 16 39	275.4
Dec. 7 7 50 49	92.4	26 8 17 46	271.2
7 8 0 31	92.6	Feb. 10 11 0 34	73.0
15 15 27 37	297.9	16 10 15 36	69.5
15 15 48 2	297.7		

The method of double distances was used for the observations of October 27, 28, December 15, 16, January 5 and 12. For other dates the method of single distances was used. Six comparisons were made for each determination of distance.

Mt. Hamilton, Cal., 1899 *May* 3.

OBSERVATIONS OF COMET 1898 VIII,

By HENRY B. EVANS.

1899 Greenwich M.T.	*	No. Comp.	☌ − * $\Delta\alpha$	☌ − * $\Delta\delta$	☌'s apparent α	☌'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Jan. 22 22 5 22	1	12, 11	+0 13.80	+2 15.2	11 10 4.22	32 44 31.3	9.450	0.221
Feb. 9 15 18 59	2	9, 10	+1 23.98	−1 40.5	11 6 7.60	35 50 59.6	n9.648	0.340
10 17 21 21	3	8	+5 38.01	+3 42.3	11 5 40.81	36 0 43.5	n9.293	9.938
14 14 23 49	4	8, 9	+0 50.37	+0 0.7	11 3 55.78	36 33 8.5	n9.694	0.415
Mar. 5 14 12 9	5	8	−0 2.33	+2 29.2	10 53 56.26	38 13 45.5	n9.589	0.133
12 17 5 27	6	9, 8	+0 53.61	+4 4.7	10 50 27.10	38 24 46.6	8.962	9.466
16 17 12 49	6	8	−0 49.41	+3 56.0	10 48 44.06	38 24 38.5	9.185	9.590
Apr. 1 13 17 14	7	9, 10	+1 37.48	−0 14.9	10 44 28.36	37 45 33.9	n9.413	9.897
1 13 17 14	8	9, 10	+1 7.93	+3 24.4	10 44 28.33	37 45 36.5	. .	. .
2 13 20 38	7	8, 10	+1 30.25	−4 31.6	10 44 21.13	37 41 17.3	n9.433	9.869
2 13 20 38	8	8, 10	+1 0.66	−0 53.3	10 44 21.06	37 41 18.9	. .	. .
3 13 1 43	8	9, 10	+0 55.14	−5 20.1	10 41 15.53	37 36 52.2	n9.438	9.941
5 14 12 2	9	6, 10	−0 59.23	+2 43.3	10 44 6.84	37 27 23.6	n8.956	9.641
16 18 33 45	10	9, 10	+1 6.72	−3 52.0	10 44 45.33	36 22 29.7	9.712	0.477
16 18 33 45	11	6, 10	−0 45.23	+0 11.4	10 44 45.41	36 22 31.2	. .	. .
29 15 8 35	12	10	+0 5.81	+0 40.6	10 48 17.53	34 49 21.4	9.404	0.088

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	11 9 47.90	+2.52	32 42 35.8	−19.7	Weisse-Bessel, 11^h, No. 126
2	11 4 40.55	+3.07	35 52 59.6	−19.5	Yarnall No. 4756
3	10 59 59.68	+3.12	35 57 20.3	−19.1	Lund A.G. Zones, 2 obs.
4	11 3 2.24	+3.17	36 33 26.7	−18.9	Brussels No. 4591
5	10 53 55.13	+3.46	38 11 32.2	−15.9	Lund A.G. Zones, 2 obs.
6	10 49 29.98	+3.51 +3.49	38 20 56.3	−14.4 −13.8	" " " "
7	10 42 47.49	+3.39	37 45 59.6	−10.8 −10.7	" " " "
8	10 43 17.01	+3.39 +3.39 +3.38	37 42 22.9	−10.8 −10.7 −10.6	" " " "
9	10 45 2.70	+3.37	37 24 50.7	−10.4	Micrometer-comparison *13
10	10 43 35.41	+3.20	36 26 30.5	− 8.8	Lund A.G. Zones, 2 obs.
11	10 45 27.44	+3.20	36 22 28.8	− 9.0	" " " "
12	10 48 8.73	+2.99	34 48 48.6	− 7.8	Micrometer-comparison *14
13	10 45 48.64	+3.37	37 19 9.9	−10.5	Lund A.G. Zones, 3 obs.
14	10 47 39.51	+2.99	34 45 43.6	− 7.8	Paris No. 13315

Jan. 22. Sky hazy, observation poor. Apr. 16. Sky hazy, very faint. Apr. 29. $\Delta\alpha$ measured directly by micrometer.

Flower Observatory, 1899 *June* 10.

REDISCOVERY AND OBSERVATION OF HOLMES'S COMET d 1899 = 1892 III,

BY C. D. PERRINE.

1899 Mt. Hamilton M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
June 10 15 2 9 (h m s)	1	6 , 9	−0 3.11	−2 51.8	1 15 31.57	+17 29 39.0	n9.674	0.653

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 15 32.83	+1.85	+17 32 22.9	+7.9	Micrometer-comparison with *2
2	1 14 56.42	+1.86	+17 35 32.0	+7.9	Auwers, Berlin A.G. 378

The comet was found with the 36-inch refractor, using a power of 270. It appears as a round nebulous mass about 30″ in diameter, with only a slight brightening at the center. The conditions were good, the sky being very clear and the star images steady. The object is very faint, however, not being brighter than 16^M, and is difficult to observe, so that the probable error of the place obtained is larger than usual.

Lick Observatory, University of California, 1899 *June* 12.

NEW ASTEROIDS.

Communicated by Prof. KREUTZ.

	M	1899	M.T.	α	δ	Daily Motion	Discoverer
		h m		h m s	° ′ ″	s ′	
EL	11.5	Mar. 31 10 13.2	Marseilles	12 59 9.6	−6 46 58		Coggia
		31 14 39.1	"	12 59 1.3	−6 45 41		
EM	11.5	Apr. 5 11 36.3	Berl. (Ur.)	13 13 4.0	−0 45	−40 +2	Witt
*EN**	9.3	June 8 12 16.0	"	18 11 56.0	−5 0	−48 +6	Witt

* Identical with (85) *Io*.

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ON THE DEVELOPMENT OF THE PERTURBATIVE FUNCTION IN TERMS OF THE ECCENTRIC ANOMALIES,

BY ALEXANDER S. CHESSIN.

In a series of papers published in this Journal (Nos. 326, 332, 442 and 452) the author has given a method by which the computation of the terms in the development of the perturbative function is greatly simplified. The object of the present paper is to indicate a further simplification for the case of the development in terms of the eccentric anomalies as given by Professor SIMON NEWCOMB in his *Astronomical Papers*, (Vol. III, Part I).

In the second of the papers mentioned above (No. 332) the author has shown that, given the terms

$$P^{m,n}_{m,n}\ ;\ Q^{m,n}_{m,n}\ ;\ R^{m,n}_{m,n}\ ;\ \ldots\ ;\quad (m,\,n=0,1,2,\ldots)$$

any other term in Prof. NEWCOMB's development can be computed by means of the formulas

$$(1)\quad\left\{\begin{aligned}
P^{m+n,\,m'+n'}_{m-n,\,m'-n'} &= \sum_{k=0}^{k=k_1}\sum_{e=0}^{e=e_1} a^{n,m}_{k0}\; b^{n',m'}_{e0}\; P^{m+n-k,\,m'+n'-e}_{m+n-k,\,m'+n'-e}\\
Q^{m+n,\,m'+n'}_{m-n,\,m'-n'} &= \sum_{k=0}^{k=k_1}\sum_{e=0}^{e=e_1} a^{n,m}_{k1}\; b^{n',m'}_{e1}\; Q^{m+n-k,\,m'+n'-e}_{m+n-k,\,m'+n'-e}\\
R^{m+n,\,m'+n'}_{m-n,\,m'-n'} &= \sum_{k=0}^{k=k_1}\sum_{e=0}^{e=e_1} a^{n,m}_{k2}\; b^{n',m'}_{e2}\; R^{m+n-k,\,m'+n'-e}_{m+n-k,\,m'+n'-e}\\
&\ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned}\right.$$

where $k_1 = m+n$ or $2n$ according as $m-n<0$ or $\geqq 0$; and $e_1 = m'+n'$ or $2n'$ according as $m'-n'<0$ or $\geqq 0$. The coefficients $a^{n,m}_{k0}$, $a^{n,m}_{k1}$, $a^{n,m}_{k2}$, ... ; $b^{n,m}_{k0}$, $b^{n,m}_{k1}$, $b^{n,m}_{k2}$, ... ; are obtained as follows. If we put

$$(2)\quad\left\{\begin{aligned}
a^{n,m}_k &= \sum_{e=0}^{e'} q^{(m+n)}_{k,e}\;\theta_{k-2e}\;a_0^{m-k+e,\,n-e}\qquad \left(e'\leqq\frac{k}{2}\right)\\
q^{(m+n)}_{k,e} &= (-1)^e\,\frac{(\mu+m+n-k+e-1)!}{e!\,(\mu+m+n-k-1)!}\\
\theta_k &= (-1)^k\,\frac{2\mu(2\mu-1)\ldots(2\mu-k+1)}{k!}\\
a_0^{k,e} &= \frac{(k+e)!}{k!\;e!}
\end{aligned}\right.$$

and denote by $b^{n,m}_k$ the result of substituting ν for μ in the expression of $a^{n,m}_k$, then

$$\begin{aligned}
a^{n,m}_{k0} &= a^{n,m}_k &&\text{for}\quad \mu = -i\\
b^{n,m}_{k0} &= b^{n,m}_k &&\text{“}\quad \nu = i\\
a^{n,m}_{k1} &= a^{n,m}_k &&\text{“}\quad \mu = 1-i\\
b^{n,m}_{k1} &= b^{n,m}_k &&\text{“}\quad \nu = 1+i\\
a^{n,m}_{k2} &= a^{n,m}_k &&\text{“}\quad \mu = 2-i\\
b^{n,m}_{k2} &= b^{n,m}_k &&\text{“}\quad \nu = 2+i\\
&\ldots\ldots\ldots\ldots
\end{aligned}$$

The modification proposed in the present paper consists in the following.

1. Instead of applying Prof. NEWCOMB's symbols $\Pi^{m,n}_{m',n'}$ to the expressions

$$\begin{aligned}
a'A_i &= b_1^{(i)} - \tfrac{1}{2}\,\sigma^2\alpha\,(b_3^{(i-1)}+b_3^{(i+1)}) + \ldots\\
a'B_i &= \tfrac{1}{2}\,\alpha b_3^{(i)} - \tfrac{3}{4}\,\sigma^2\alpha^2\,(b_5^{(i-1)}+b_5^{(i+1)}) + \ldots\\
a'C_i &= \tfrac{3}{8}\,\alpha^2 b_5^{(i)} - \ldots\\
&\ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned}$$

we now apply these symbols to the same expressions multiplied respectively by $(1+\epsilon^2)^i(1+\epsilon'^2)^{-i}$; $(1+\epsilon^2)^{i-1}(1+\epsilon'^2)^{-i-1}$; $(1+\epsilon^2)^{i-2}(1+\epsilon'^2)^{-i-2}$; ..... To avoid new lettering we will retain the notation

$$\underset{(i)}{P}{}^{m,n}_{m',n'}\ ;\ \underset{(i)}{Q}{}^{m,n}_{m',n'}\ ;\ \underset{(i)}{R}{}^{m,n}_{m',n'}\ ;\ \ldots$$

for the respective results of this operation.

2. Instead of the $P^{m,n}_{m',n'}$; $Q^{m,n}_{m',n'}$; $R^{m,n}_{m',n'}$; .... we will introduce new quantities $X^{m,n}_{m',n'}$; $Y^{m,n}_{m',n'}$; $Z^{m,n}_{m',n'}$; .... which are defined as follows:

$$\left.\begin{aligned}
X^{m,n}_{m,n} &= (1+\epsilon^2)^{-m}\,(1+\epsilon'^2)^{-n}\,P^{m,n}_{m,n}\\
Y^{m,n}_{m,n} &= (1+\epsilon^2)^{-m}\,(1+\epsilon'^2)^{-n}\,Q^{m,n}_{m,n}\\
Z^{m,n}_{m,n} &= (1+\epsilon^2)^{-m}\,(1+\epsilon'^2)^{-n}\,R^{m,n}_{m,n}\\
&\ldots\ldots\ldots\ldots
\end{aligned}\right\}\qquad(3)$$

$$(4)\quad\left\{\begin{aligned}
X^{m+n,\,m'+n'}_{m-n,\,m'-n'} &= \sum_{k=0}^{k=k_1}\sum_{e=0}^{e=e_1} \alpha^{n,\,m}_{k0}\,\beta^{n',\,m'}_{e0}\,X^{m+n-k,\,m'+n'-e}_{m+n-k,\,m'+n'-e}\\
Y^{m+n,\,m'+n'}_{m-n,\,m'-n'} &= \sum_{k=0}^{k=k_1}\sum_{e=0}^{e=e_1} \alpha^{n,\,m}_{k1}\,\beta^{n',\,m'}_{e1}\,Y^{m+n-k,\,m'+n'-e}_{m+n-k,\,m'+n'-e}\\
Z^{m+n,\,m'+n'}_{m-n,\,m'-n'} &= \sum_{k=0}^{k=k_1}\sum_{e=0}^{e=e_1} \alpha^{n,\,m}_{k2}\,\beta^{n',\,m'}_{e2}\,Z^{m+n-k,\,m'+n'-e}_{m+n-k,\,m'+n'-e}\\
&\ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned}\right.$$

where the coefficients $\alpha^{n,\,m}_{k0}$, $\alpha^{n,\,m}_{k1}$, ... ; $\beta^{n,\,m}_{k0}$, $\beta^{n,\,m}_{k1}$, ... are obtained from $\alpha^{n,\,m}_{k}$ and $\beta^{n,\,m}_{k}$ in the same way as the coefficients $a^{n,\,m}_{k0}$, $a^{n,\,m}_{k1}$, ... ; $b^{n,\,m}_{k0}$, $b^{n,\,m}_{k1}$, ... are obtained from $a^{n,\,m}_{k}$ and $b^{n,\,m}_{k}$; again $\beta^{n,\,m}_{k}$ is obtained from $\alpha^{n,\,m}_{k}$ by changing μ into ν and

$$(5)\qquad \alpha^{n,\,m}_{k} = \theta_k\, a^{n-k,\,m}_{0}$$

3. The general terms of the several classes in the development will be now

(Class 0) $\quad \epsilon^n\epsilon'^{n'}\underset{(0)}{X^{n,\,n'}_{m,\,m'}}\cos(V_i+m\eta+m'\eta')$

(Class 1) $\quad \sigma^2\epsilon^n\epsilon'^{n'}\underset{(0)}{Y^{n,\,n'}_{m,\,m'}}\cos(V_i'+m\eta+m'\eta')$

(Class 2) $\quad \sigma^4\epsilon^n\epsilon'^{n'}\underset{(0)}{Z^{n,\,n'}_{m,\,m'}}\cos(V_i''+m\eta+m'\eta')$

. . . .

To obtain the developed value of the perturbative function with the new coefficients, it is only necessary to replace the letters P, Q, R, ... *by the letters* X, Y, Z, ... *in the complete development given in Chapter V, of Prof.* NEWCOMB'S *work* (*Astron. Papers*, Vol. III, Part I.)

It will be seen from the above that *the advantage of the proposed modification consists in the more simple form of the relations* (4), *as compared with the relations* (1). In fact the computation of the $X^{m,\,n}_{m,\,n}$; $Y^{m,\,n}_{m,\,n}$; .... requires only a slight additional calculation as compared with the computation of the original $P^{m,\,n}_{m,\,n}$; $Q^{m,\,n}_{m,\,n}$; .... ,(*) while to the simplicity of the relations (4) as compared with (1) we owe a sensible reduction in the work of computing the other coefficients in the development of the perturbative function. This simplification is two fold. First, *the coefficients* $\alpha^{n,\,m}_{k}$, $\beta^{n,\,m}_{k}$ *are very much simpler than the coefficients* $a^{n,\,m}_{k}$ *and* $b^{n,\,m}_{k}$. Second, as is seen from formula (5) we must have $k \leq n$, hence $k_1 = n$ and for a similar reason $e_1 = n'$ in formulas (4), while k_1 and e_1 are equal to $m+n$ or $2n$ and $m'+n'$ or $2n'$, respectively, in formulas (1), so that *there are fewer terms in the double sums* (4) *than in the double sums* (1).

It must be shown now that the proposed modification is justifiable.

In order to demonstrate it at once for all classes of terms we will denote any one of the coefficients P, Q, R, ... by the letter H, and any one of the coefficients X, Y, Z, ... by the letter U, so that

$$\begin{aligned}
\underset{(0)}{P^{n,\,n'}_{m,\,m'}} &= \underset{(\mu,\,\nu)}{H^{n,\,n'}_{m,\,m'}} \quad\text{for}\quad \mu = -i \quad\text{and}\quad \nu = i\\
\underset{(0)}{Q^{n,\,n'}_{m,\,m'}} &= \underset{(\mu,\,\nu)}{H^{n,\,n'}_{m,\,m'}} \quad\text{for}\quad \mu = 1-i \quad\text{and}\quad \nu = 1+i\\
&\ldots\ldots\ldots\ldots\ldots\ldots\\
\underset{(0)}{X^{n,\,n'}_{m,\,m'}} &= \underset{(\mu,\,\nu)}{U^{n,\,n'}_{m,\,m'}} \quad\text{for}\quad \mu = -i \quad\text{and}\quad \nu = i\\
\underset{(0)}{Y^{n,\,n'}_{m,\,m'}} &= \underset{(\mu,\,\nu)}{U^{n,\,n'}_{m,\,m'}} \quad\text{for}\quad \mu = 1-i \quad\text{and}\quad \nu = 1+i\\
&\ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned}$$

Moreover, we will denote by $N_{\mu,\nu}$ the values of V_i, V_i', V_i'', ... of Prof. NEWCOMB. With this notation, any term in the developed value of the perturbative function may be represented in the form

$$\sigma^{2k}\Big(\sum_n\sum_{n'}\epsilon^n\epsilon'^{n'}\underset{(\mu,\,\nu)}{H^{n,\,n'}_{m,\,m'}}\Big)\cos(N_{\mu,\nu}+m\eta+m'\eta')$$

using the original coefficients of Prof. NEWCOMB,(*) or in the form

$$\sigma^{2k}\Big(\sum_n\sum_n\epsilon^n\epsilon'^{n'}\underset{(\mu,\,\nu)}{U^{n,\,n'}_{m,\,m'}}\Big)\cos(N_{\mu,\nu}+m\eta+m'\eta')$$

using the new coefficients. The proposition to be proved is therefore

$$\sum_n\sum_{n'}\epsilon^n\epsilon'^{n'}H^{n,\,n'}_{m,\,m'} = \sum_n\sum_{n'}\epsilon^n\epsilon'^{n'}U^{n,\,n'}_{m,\,m'}$$

The demonstration will be greatly simplified if we make use of a remarkable theorem due to Prof. NEWCOMB(†), namely : *if the perturbative function be developed in the supposition* $\epsilon' = 0$ *and any term in this development be represented in the form*

$$\Big(\sum_n\epsilon^n\underset{(\mu)}{H^n_m}A\Big)\cos(N_{\mu,\nu}+m\eta)$$

and if, on the other hand, the development were made in the supposition $\epsilon = 0$, *the general term being now*

$$\Big(\sum\epsilon'^{n'}\underset{(\nu)}{H^{0,\,n'}_{0,\,m'}}A\Big)\cos(N_{\mu,\nu}+m'\eta')$$

then the coefficient of $\cos(N_{\mu,\nu}+m\eta+m'\eta')$ *in the complete development will be represented by*

$$\sum_n\sum_{n'}\epsilon^n\epsilon'^{n'}\underset{(\mu,\,\nu)}{H^{n,\,n'}_{m,\,m'}}$$

This theorem applies as well in the case when the coefficients U are used as in that when we retain the original coefficients H of Prof. NEWCOMB. Hence we may restrict ourselves to proving that

$$\sum_n\epsilon^n H^n_m = \sum_n\epsilon^n U^n_m$$

or, since $n = m+2p$ $(p = 0, 1, 2, \ldots)$

(*) A simple method for computing these coefficients will be found in a paper by the author in No. 326 of this Journal.

* For $m = m' = k = 0$ the above expression as well as the one we propose to substitute for it must be multiplied by the factor $\frac{1}{2}$.

(†) *Astronomical Papers*, Vol. III, Part I, p. 28.

(6) $$\sum_{p=0}^{p=\infty} \epsilon^{2p}\, H_m^{m+2p} = \sum_{p=0}^{p=\infty} \epsilon^{2p}\, U_m^{m+2p}$$

To this proof we now proceed. To this end we remark that by the relations (4)

(7) $$U_m^{m+2p} = \alpha_0^{p,\,m+p}\, U_{m+2p}^{m+2p} + \alpha_1^{p,\,m+p}\, U_{m+2p-1}^{m+2p-1} + \ldots + \alpha_{2p}^{p,\,m+p}\, U_m^m$$

where the coefficients α must be put $= 0$ if they stand before a term U_k^k whose index k is negative. On the other hand we have by relations (3)

(8) $$U_k^k = (1+\epsilon^2)^{-\mu-k}\, H_k^k$$

remembering that P, Q, R, ... in those formulas are Prof. Newcomb's coefficients multiplied by $(1+\epsilon^2)^{-\mu}$. If now we develop the binomial in (8) and substitute the so developed values of the U_k^k into (7), and, finally, the developed values of U_m^{m+2p} into (6), then the right hand side of (6) will become

(9) $$\sum_{q=0}^{q=\infty} \epsilon^{2q}\, C_q^{(m)}$$

where

(10) $$C_q^{(m)} = \sum_{k=0}^{k=k_1} c_k^{m,\,q}\, H_{m+2q-k}^{m+2q-k}$$

(11) $$\left\{\begin{aligned} c_{2k}^{m,\,q} &= \sum_{e=0}^{e=k} q_{2k,\,e}^{(m+2q)}\, \alpha_{2k-2e}^{q-e,\,m+q-e} \\ c_{2k-1}^{m,\,q} &= \sum_{e=0}^{e=k-1} q_{2k-1,\,e}^{(m+2q)}\, \alpha_{2k-1-2e}^{q-e,\,m+q-e} \end{aligned}\right.$$

Formulas (11) compared to formulas (2) and (5) show that $c_k^{m,q} = a_k^{m,q}$ and, therefore,

$$C_q^{(m)} = \sum_{k=0}^{k=k_1} a_k^{m,\,q}\, H_{m+2q-k}^{m+2q-k} = H_m^{m+2q}$$

as will be seen from formulas (1). Hence

$$\sum_{p=0}^{p=\infty} \epsilon^{2p}\, U_m^{m+2p} = \sum_{q=0}^{q=\infty} \epsilon^{2q}\, C_q^{(m)} = \sum_{q=0}^{q=\infty} \epsilon^{2q}\, H_m^{m+2q}.$$

which proves our proposition.

The proposed modification changes in nothing the process of derivation D (symbol of the derivative with regard to the logarithm of the mean distance of the inner planet). If the method given by the author in No. 332 of this Journal be used for computing the $DP_{m,n}^{m,n}$, $DQ_{m,n}^{m,n}$, ... (see formulas (60)-(62) *l.c.*) the same formulas will give the values of these coefficients for the modified values of the P, Q, ... This being done, we shall have

$$DU_{m,n}^{m,n} = (1+\epsilon^2)^{-m}\,(1+\epsilon'^2)^{-n}\, DH_{m,n}^{m,n}$$

while the $DU_{m',n'}^{m,n}$, where $m \pm m'$ and $n \pm n'$ will be given by formulas differing from (4) only in the substitution of DU for U.

To resume, the computation of the terms of the perturbative function will be made in the following order:

1. First compute the coefficients

$$\begin{aligned} &A_i\,(1+\epsilon^2)^{i}\,(1+\epsilon'^2)^{-i} \\ &B_i\,(1+\epsilon^2)^{i-1}\,(1+\epsilon'^2)^{-i-1} \\ &C_i\,(1+\epsilon^2)^{i-2}\,(1+\epsilon'^2)^{-i-2} \\ &\ldots\ldots\ldots\ldots \end{aligned}$$

where A_i, B_i, C_i, ... are given by formulas (11) of Prof. Newcomb's work referred to above. It may in some cases be convenient to first develop the binomials and thus start with developments in powers of both σ^2 and ϵ^2, ϵ'^2. In general, however, the form given here will be more advantageous.

2. Compute the coefficients $X_{m,n}^{m,n}$, $Y_{m,n}^{m,n}$, $Z_{m,n}^{m,n}$, ... as explained in Nos. 326 and 332 of this Journal: the computation of these coefficients differs from that of the $P_{m,n\,(i)}^{m,n}$, $Q_{m,n\,(i)}^{m,n}$, ... used there only in adding to the latter the factors $(1+\epsilon^2)^{-m}\,(1+\epsilon'^2)^{-n}$.

3. Compute the coefficients $X_{m',n'\,(i)}^{m,n}$, $Y_{m',n'\,(i)}^{m,n}$, $Z_{m',n'}^{m,n}$ .... by means of formulas (4).

4. The computation of the derivatives of the several terms of the perturbative function with regard to the logarithm of the mean distance of the inner planet proceeds in a similar way.

To conclude, as formulas (4) in their general form may not give an adequate idea of their simplicity, we will write down those of them which are to be used for practical purposes. Again the letter U will be used to denote X, Y, Z, ... when the class of the term is not specified.

$$U_{m-1,\,m'}^{m+1,\,m'} = (m+1)\, U_{m+1,\,m'}^{m+1,\,m'} - 2\mu\, U_{m,\,m'}^{m,\,m'}$$

$$U_{m-2,\,m'}^{m+2,\,m'} = \frac{(m+2)(m+1)}{2}\, U_{m+2,\,m'}^{m+2,\,m'} - 2\mu\,(m+1)\, U_{m+1,\,m'}^{m+1,\,m'} + \frac{2\mu\,(2\mu-1)}{2}\, U_{m,\,m'}^{m,\,m'}$$

$$U_{m-3,\,m'}^{m+3,\,m'} = \frac{(m+3)(m+2)(m+1)}{3\,!}\, U_{m+3,\,m'}^{m+3,\,m'} - 2\mu\,\frac{(m+2)(m+1)}{2}\, U_{m+2,\,m'}^{m+2,\,m'} + \frac{2\mu\,(2\mu-1)}{2}\,(m+1)\, U_{m+1,\,m'}^{m+1,\,m'} - \frac{2\mu\,(2\mu-1)(2\mu-2)}{3\,!}\, U_{m,\,m'}^{m,\,m'}$$

In a similar way we have

$$U_{m',\,m-1}^{m',\,m+1} = (m+1)\, U_{m',\,m+1}^{m',\,m+1} - 2\nu\, U_{m',\,m}^{m',\,m}$$

$$U_{m',\,m-2}^{m',\,m+2} = \frac{(m+2)(m+1)}{2}\, U_{m',\,m+2}^{m',\,m+2} - 2\nu\,(m+1)\, U_{m',\,m+1}^{m',\,m+1} + \frac{2\nu\,(2\nu-1)}{2}\, U_{m',\,m}^{m',\,m}$$

$$U_{m',\,m-3}^{m',\,m+3} = \frac{(m+3)(m+2)(m+1)}{3\,!}\, U_{m',\,m+3}^{m',\,m+3} - 2\nu\,\frac{(m+2)(m+1)}{2}\, U_{m',\,m+2}^{m',\,m+2} + \frac{2\nu\,(2\nu-1)}{2}\,(m+1)\, U_{m',\,m+1}^{m',\,m+1} - \frac{2\nu(2\nu-1)(2\nu-2)}{3\,!}\, U_{m',\,m}^{m',\,m}$$

These formulas are easily continued. We obtain as readily the following ones:

$$U^{m+1,\,n+1}_{m-1,\,n-1} = (m+1)(n+1)\,U^{m+1,\,n+1}_{m+1,\,n+1} - 2\mu(n+1)\,U^{m,\,n+1}_{m,\,n+1} - 2\nu(m+1)\,U^{m+1,\,n}_{m+1,\,n} + 4\mu\nu\,U^{m,\,n}_{m,\,n}$$

$$\begin{aligned} U^{m+2,\,n+1}_{m-2,\,n-1} = {} & \frac{(m+2)(m+1)(n+1)}{2}\,U^{m+2,\,n+1}_{m+2,\,n+1} - \nu(m+2)(m+1)\,U^{m+2,\,n}_{m+2,\,n} \\ & - 2\mu(m+1)(n+1)\,U^{m+1,\,n+1}_{m+1,\,n+1} + 4\mu\nu(m+1)\,U^{m+1,\,n}_{m+1,\,n} \\ & - \mu(2\mu-1)(n+1)\,U^{m,\,n+1}_{m,\,n+1} - 2\nu\mu(2\mu-1)\,U^{m,\,n}_{m,\,n} \end{aligned}$$

$$\begin{aligned} U^{m+1,\,n+2}_{m-1,\,n-2} = {} & \frac{(n+2)(n+1)(m+1)}{2}\,U^{m+1,\,n+2}_{m+1,\,n+2} - \mu(n+2)(n+1)\,U^{m,\,n+2}_{m,\,n+2} \\ & - 2\nu(n+1)(m+1)\,U^{m+1,\,n+1}_{m+1,\,n+1} + 4\nu\mu(n+1)\,U^{m,\,n+1}_{m,\,n+1} \\ & - \nu(2\nu-1)(m+1)\,U^{m+1,\,n}_{m+1,\,n} - 2\mu\nu(2\nu-1)\,U^{m,\,n}_{m,\,n} \end{aligned}$$

$$\begin{aligned} U^{m+2,\,n+2}_{m-2,\,n-2} = {} & \frac{(m+2)(m+1)(n+2)(n+1)}{4}\,U^{m+2,\,n+2}_{m+2,\,n+2} \\ & - \nu(m+2)(m+1)(n+1)\,U^{m+2,\,n+1}_{m+2,\,n+1} - \mu(n+2)(n+1)(m+1)\,U^{m+1,\,n+2}_{m+1,\,n+2} \\ & + 4\mu\nu(m+1)(n+1)\,U^{m+1,\,n+1}_{m+1,\,n+1} + \frac{2\mu(2\mu-1)(n+2)(n+1)}{4}\,U^{m,\,n+2}_{m,\,n+2} \\ & + \frac{2\nu(2\nu-1)(m+2)(m+1)}{4}\,U^{m+2,\,n}_{m+2,\,n} - 2\mu\nu(2\mu-1)(n+1)\,U^{m,\,n+1}_{m,\,n+1} \\ & - 2\mu\nu(2\nu-1)(m+1)\,U^{m+1,\,n}_{m+1,\,n} + \mu\nu(2\mu-1)(2\nu-1)\,U^{m,\,n}_{m,\,n} \end{aligned}$$

These few formulas suffice to illustrate the method. It would be out of place to give them in detail on the pages of this Journal, since this would consume too much room.

New York, 1898 *November* 10.

OBSERVATIONS OF MINOR PLANETS AND COMET a 1899,

MADE AT THE OBSERVATORY OF VASSAR COLLEGE WITH THE 12-INCH REFRACTOR,

By MARY W. WHITNEY AND ALICE EVERETT.

1899 Greenwich M.T.	✱	No. Comp.	Planet — ✱ $\Delta\alpha$	Planet — ✱ $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
				(385) *Ilmatar.*					
	h m s		m s	′ ″	h m s	° ′ ″			
Apr. 12 15 44 8	1	6	+1 9.50	−9 9.2	12 10 6.40	−12 45 12.9	7.763	0.856	W
15 14 37 28	1	5	−1 19.24	−5 23.6	12 7 37.67	−12 41 27.6	n8.987	0.853	W
18 15 20 35	2	6	+1 8.51	−9 3.7	12 5 16.25	−12 37 30.3	8.187	0.856	W
				(287) *Nephthys.*					
Apr. 15 16 23 31	3	7	+2 7.96	+1 8.6	14 14 4.47	+ 3 34 9.1	n9.122	0.736	W
				(17) *Thetis.*					
Apr. 27 14 39 51	4	6	+1 39.82	−1 15.9	15 46 28.42	− 9 49 14.6	n9.563	0.808	AE
May 2 16 27 31	5	10	+2 18.30	−7 20.7	15 42 41.54	− 9 30 50.5	n9.221	0.832	AE
4 16 11 30	5	14	+0 41.49	−0 29.4	15 41 4.74	− 9 23 59.2	n9.251	0.830	AE
				(346) *Hermentaria.*					
May 2 14 54 5	6	3	−1 53.57	+6 28.7	12 0 31.50	+12 36 16.0	n8.908	0.853	W
4 13 46 47	6	7	−2 30.58	+3 21.2	11 59 54.47	+12 33 8.7	n8.545	0.854	W
6 16 29 26	7	7	+1 47.41	+3 10.4	11 59 18.78	+12 29 17.7	9.449	0.835	W
				(423) [1896 DB.]					
May 8 15 15 15	8	6	+0 30.57	−1 33.1	13 50 14.64	− 0 38 30.5	n8.658	0.773	W
9 14 48 37	8	8	−0 11.76	−1 49.3	13 49 32.31	− 0 38 46.6	n8.942	0.773	W
10 16 53 34	8	9	−0 57.85	−2 11.7	13 48 46.22	− 0 39 8.9	9.200	0.773	W
11 14 45 57	8	6	−1 35.32	−2 43.1	13 48 8.76	− 0 39 40.3	n8.875	0.773	W
				(118) *Peitho.*					
May 8 16 42 20	9	17	+0 26.64	+0 19.4	14 4 46.60	−10 35 34.9	8.980	0.842	AE
9 16 21 53	9	13	−0 27.14	+2 5.0	14 3 52.82	−10 33 49.3	8.815	0.842	AE
				COMET a 1899.					
May 30 15 39 3	10	6	+2 26.66	+3 35.5	18 45 15.88	+57 13 57.5	n9.808	n9.410	AE
31 15 57 39	11	4	−3 16.76	−8 43.2	18 20 13.85	+56 46 43.0	n9.715	n0.011	AE
June 6 16 18 0	12	3	−2 41.10	−7 25.5	16 23 58.94	+49 21 9.4	n6.620	n0.082	AE
				COMET a 1899.					
June 3 14 46 29	13	6	−1 17.11	+1 18.7	17 15 8.27	+53 53 22.3	n9.670	n9.858	W

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	12 8 53.85	+3.05	−12 35 42.7	−21.0	Compared with Bessel XII, 96
2	12 4 4.70	+3.04	−12 28 5.0	−21.6	Harvard Observatory
3	14 11 53.37	+3.14	+ 3 33 18.7	−18.2	Boss, Albany A.G. Catal. 4916
4	15 44 45.26	+3.34	− 9 47 45.7	−13.0	Bessel XV, 812
5	15 40 19.79	+3.45	− 9 23 16.5	−13.3	" XV, 724
6	12 2 22.08	+2.99	+12 30 3.4	−16.1	" XI, 1018
7	11 57 28.44	+2.93	+12 26 22.9	−15.6	" XI, 946
8	13 49 40.80	+3.27	− 0 36 39.8	−17.6	Göttingen, 1090
9	14 4 16.56	+3.40	−10 35 36.1	−18.2	Munich I, 9884
10	18 42 46.28	+2.94	+57 10 29.0	− 7.0	Helsingfors-Gotha, A.G. Catal. 9959
11	18 23 27.57	+3.04	+56 55 32.9	− 6.7	Helsingfors-Gotha, A.G. Catal. 9789
12	16 26 36.75	+3.29	+49 28 39.0	− 4.1	Deichmüller Bonn A.G. Catal. 10566
13	17 16 22.13	+3.25	+53 52 8.9	− 5.3	Rogers, Cambridge A.G. Catal. 5223 [1]

MEASURES OF THE DIAMETER OF *JUPITER*,

BY HENRY NORRIS RUSSELL.

The following measures were made with the filar micrometer of the 23-inch equatorial of the Halsted Observatory. They are double-distance measures, corrected for the diameter of the wires. The magnifying power used was 360. The average difference between the greatest and least measures of a single night was 0″.32.

Greenwich M.T.	No. of Settings	Equatorial Diameter Observed	Phase	Corr. Val.	Dist. 5.202	Polar Diameter Observed	Dist. 5.202
h		″	″	″	″	″	″
1899 May 22, 14	5	44.37	+0.09	44.46	38.68	41.87	36.42
24, 15	5	44.28	+0.11	44.39	38.75	41.64	36.35
25, 14.5	10	44.03	+0.11	44.14	38.60	41.39	36.21
June 7, 16	6	42.87	+0.20	43.07	38.70	40.26	36.17
8, 15	5	42.79	+0.21	43.00	38.73	40.14	36.16
		Mean			38.676		36.253
		Diameter at distance unity			201.24		188.60
		Oblateness $\frac{1}{15.9}$					

On June 5 the planet was observed through thin clouds. Though it was faint, its outlines were sharp, and the following measures were secured. The individual measures agree as well as on other nights.

Greenwich M.T.	No. of Settings	Equatorial Diameter Observed	Phase	Corr. Val.	Dist. 5.202	Polar Diameter Observed	Dist. 5.202
h		″	″	″	″	″	″
1899 June 5, 16	5	42.45	+0.19	42.64	38.15	39.93	35.72

From these measures it appears that the irradiation is probably at least 0″.6 on the planet's diameter, or 0″.3 at each limb, and that the true equatorial and polar diameters of the planet at its mean distance are consequently not more than 38″.1 and 35″.7 respectively.

Princeton University, 1899 *June* 9.

MINIMUM OF CERASKI'S NEW *ALGOL*-TYPE VARIABLE.

DM. +45°3062, $\alpha = 20^h\ 2^m\ 24^s.5$, $\delta = +45°\ 52'.9$, (1855),

BY J. A. PARKHURST.

The following observations seem to confirm the period, $4^d.572$, given in *A.N.* 3572.

GREENWICH TIME.

1899	h	M	
June 15	15.1	8.80	Moon
19	15.0	8.55	"
21	14.8	8.66	"
23	15.0	8.66	"
June 26	14.9	9.71	
	15.3	10.10	
	16.2	10.18	
	16.3	10.50	
June 26	16.7	10.69	
	16.8	11.00	
June 26	17.0	11.12	
	17.1	11.26	

The magnitudes are based on the DM. scale and are only approximate. The minimum was evidently passed not far from June 26, 18^h, the ephemeris time was $17^h.9$. Taking the minimum of 1899 May 7, $10^h.9$, as the zero epoch, the above is No. 11.

SUNSPOT OBSERVATIONS,

MADE AT BERWYN, PENNA., WITH A 4½-INCH REFRACTOR,

By A. W. QUIMBY.

1899	Time	New Grs.	Total Grs.	Total Spots	Fac. Grs.	Def.
Jan. 1	12	2	2	10	1	fair
2	3	1	3	11	1	fair
3	8	–	1	11	–	poor
4	12	–	1	1	–	v.poor
7	9	1	2	12	–	poor
8	9	–	2	9	–	poor
10	9	–	1	7	–	poor
11	12	1	2	12	1	fair
15	9	–	2	15	3	good
16	11	1	2	7	1	poor
17	9	–	2	8	1	fair
18	8	–	1	3	1	poor
19	8	–	1	1	1	poor
20	9	–	–	–	2	good
21	9	–	–	–	–	fair
22	9	–	–	–	–	poor
23	4	–	–	–	–	fair
24	9	1	1	1	–	poor
25	1	–	1	4	1	fair
26	8	–	1	6	1	fair
27	9	–	1	7	–	poor
29	9	–	1	2	–	poor
30	9	1	2	7	1	fair
31	10	–	1	1	–	v.poor
Feb. 1	9	1	2	11	1	fair
2	9	–	2	23	2	good
3	9	–	2	7	–	poor
4	10	–	2	10	–	fair
7	10	–	1	8	–	poor
8	12	–	–	–	–	v.poor
9	9	–	1	4	1	poor
10	8	–	1	3	1	poor
11	10	–	1	2	1	poor
14	9	–	–	–	–	fair
15	8	–	–	–	–	fair
17	8	–	–	–	–	fair
18	8	–	–	–	1	fair
19	1	–	–	–	1	fair
20	8	–	–	–	1	fair
21	8	–	–	–	1	poor
22	9	–	–	–	1	fair
23	8	1	1	1	–	fair
24	8	–	–	–	–	fair
25	8	–	–	–	–	fair
27	11	1	1	2	–	fair
28	9	–	1	10	–	good
Mar. 1	10	–	1	6	–	poor
3	8	–	1	4	1	poor
5	1	–	–	–	–	fair
6	8	–	–	–	–	poor
8	8	–	–	–	–	fair
9	8	–	–	–	–	fair
10	8	–	–	–	2	poor
Mar. 11	10	1	1	1	2	fair
12	8	–	1	1	1	fair
13	8	–	1	2	1	fair
14	8	–	1	4	–	fair
16	8	1	1	10	1	poor
17	8	–	1	32	1	fair
19	1	–	1	20	–	poor
20	8	1	2	38	1	fair
21	8	–	2	20	–	poor
23	10	1	3	6	1	poor
24	4	–	3	7	1	poor
26	2	1	3	8	2	fair
27	8	–	2	4	2	fair
29	9	–	1	1	–	fair
30	8	–	1	5	1	fair
31	11	–	1	2	–	poor
Apr. 1	8	–	1	3	1	fair
2	8	–	1	2	–	fair
3	8	–	1	3	–	fair
4	8	1	2	3	–	poor
5	7	–	2	2	–	fair
6	8	–	1	2	–	fair
7	8	–	–	–	–	poor
8	8	–	–	–	–	fair
9	9	1	1	1	1	poor
10	8	–	1	2	–	poor
11	8	2	3	10	2	fair
12	8	–	3	8	2	fair
13	8	–	2	8	2	fair
14	8	–	2	2	–	poor
15	8	–	1	1	–	poor
16	12	–	1	1	–	poor
17	8	2	2	3	1	poor
18	8	–	1	1	1	poor
19	9	–	1	1	1	fair
20	8	1	1	1	2	fair
21	8	–	1	1	2	fair
22	8	–	1	1	2	fair
23	8	1	2	3	1	fair
24	8	–	2	2	1	fair
25	8	–	2	2	1	fair
26	8	–	2	5	–	fair
27	11	–	1	9	–	good
28	8	–	1	10	–	good
29	9	–	1	6	–	fair
30	8	–	1	2	1	poor
May 1	8	–	1	1	1	poor
2	8	–	1	1	–	poor
3	8	–	1	1	1	fair
4	8	–	1	1	1	fair
5	8	–	–	–	1	good
6	8	–	–	–	–	fair
7	8	–	–	–	–	fair
May 8	8	–	–	–	–	poor
9	8	–	–	–	1	good
10	8	–	–	–	–	fair
11	8	–	–	–	–	poor
12	8	–	–	–	–	fair
13	8	–	–	–	–	v.poor
14	8	–	–	–	–	fair
15	10	–	–	–	–	poor
16	6	–	–	–	–	poor
17	8	–	–	–	–	fair
19	11	–	–	–	–	poor
20	8	1	1	2	1	fair
21	8	–	1	2	1	fair
22	8	–	1	4	2	fair
23	8	–	1	5	1	fair
24	8	–	1	4	–	poor
25	8	–	1	4	–	fair
26	8	–	1	5	1	fair
27	8	–	1	1	1	poor
28	8	–	1	1	–	fair
29	8	–	1	1	1	fair
30	8	–	1	1	1	fair
31	4	–	1	4	1	good
June 1	8	–	1	1	1	fair
2	8	–	–	–	–	good
3	8	1	1	1	1	fair
4	8	–	1	5	1	fair
5	8	1	2	6	2	fair
6	8	–	1	5	–	poor
7	5	–	1	3	–	poor
8	7	1	2	5	2	fair
9	8	1	3	13	2	fair
10	6	–	2	10	2	fair
11	8	–	1	4	1	v.poor
12	11	–	–	–	–	v.poor
13	8	1	1	7	–	poor
14	4	–	2	28	1	v.good
15	8	–	2	27	–	fair
16	8	1	3	18	1	fair
17	8	–	3	14	2	fair
18	5	–	2	3	1	fair
19	8	–	1	1	–	fair
20	8	–	1	1	–	fair
21	8	–	–	–	1	fair
22	8	–	–	–	1	fair
23	5	1	1	2	1	fair
24	8	–	1	2	1	fair
25	8	–	1	1	–	poor
26	8	–	1	18	–	fair
27	8	–	1	27	–	good
28	8	–	1	10	–	poor
29	5	–	1	22	–	fair
30	7	–	1	20	1	fair

OBSERVATIONS OF SUNSPOTS,

MADE AT BOSTON UNIVERSITY OBSERVATORY,

By A. I. OLIVER, J. J. RYAN, and W. A. COIT, Students in Astronomy.

W. M. T. 1898-9		Groups N	Groups S	Spots in Grs. N	Spots in Grs. S	Isolated Spots N	Isolated Spots S	Totals Gps.	Totals Spots	Def.
	d h									
Sept.	26 4	1	0	5	0	0	0	1	5	E
	27 0	2	0	9	0	0	0	2	9	G
	28 23	1	1	10	4	0	0	2	14	G
	30 1	1	2	30	26	0	0	3	56	E
	30 22	1	2	25	24	0	0	3	49	G
Oct.	3 0	1	2	9	33	0	0	3	42	G
	3 23	1	2	2	17	0	0	3	19	G
	6 3	1	2	3	12	0	1	3	16	E
	6 23	0	3	0	28	0	0	3	28	E
	9 21	0	2	0	14	0	0	2	14	G
	10 4	0	1	0	4	0	1	1	5	F
	11 4	0	2	0	14	0	0	2	14	G
	11 23	0	1	0	12	0	0	1	12	G
	12 4	0	1	0	4	1	0	1	5	G
	13 1	0	1	0	7	1	0	1	8	P
	17 4	1	0	3	0	0	1	1	4	G
	20 2	0	1	0	5	0	0	1	5	G
	24 1	1	0	11	0	0	0	1	11	G
	25 4	2	1	15	2	0	0	3	17	G
	26 23	2	1	24	2	0	1	3	27	P
	28 2	3	0	29	0	1	0	3	30	F
Nov.	1 2	2	1	16	7	1	0	3	24	G
	2 0	2	2	29	16	1	0	4	46	G
	2 22	1	2	28	16	2	0	3	46	G
	3 22	1	2	31	16	0	0	3	47	F
	7 3	1	2	15	11	0	0	3	26	F
	8 23	1	1	10	15	0	0	2	25	F
	10 23	1	1	3	6	0	0	2	9	F
	15 23	1	0	6	0	0	0	1	6	G
	21 1	0	1	0	5	0	0	1	5	G
	24 21	0	0	0	0	1	0	0	1	G
	28 23	1	0	5	0	0	1	1	6	G
Dec.	1 23	0	2	0	5	0	0	2	5	E
	5 23	0	2	0	7	0	0	2	7	P
	7 1	0	2	0	18	0	0	2	18	E
	8 0	0	1	0	16	0	0	1	16	G
	9 0	0	1	0	6	0	0	1	6	G
	13 1	0	1	0	3	0	0	1	3	F
	13 23	0	0	0	0	0	0	0	0	F
	15 1	0	0	0	0	0	0	0	0	F
	15 23	1	0	2	0	1	0	1	3	G
	18 23	1	0	4	0	0	0	1	4	G
	22 1	1	0	3	0	0	0	1	3	F
	23 1	1	0	4	0	0	0	1	4	F
	30 0	0	1	0	14	0	1	1	15	G
1899 Jan.	2 3	0	2	0	22	0	1	2	23	G
	4 3	0	1	0	10	0	0	1	10	P
	7 3	0	2	0	11	0	0	2	11	G

W. M. T. 1899		Groups N	Groups S	Spots in Grs. N	Spots in Grs. S	Isolated Spots N	Isolated Spots S	Totals Gps.	Totals Spots	Def.
	d h									
Jan.	10 3	0	2	0	7	0	0	2	7	F
	11 1	0	2	0	10	0	0	2	10	P
	12 3	0	1	0	13	0	0	1	13	G
	16 22	0	1	0	7	0	1	1	8	G
	17 23	0	1	0	2	0	0	1	2	F
	18 23	0	1	0	2	0	0	1	2	F
	20 4	0	0	0	0	0	1	0	1	E
	23 3	0	1	0	3	0	0	1	3	G
	25 1	0	1	0	8	0	0	1	8	G
	27 2	0	1	0	9	0	0	1	9	P
	29 23	0	2	0	7	0	0	2	7	P
Feb.	1 0	0	1	0	8	0	1	1	9	F
	1 22	0	1	0	6	0	1	1	7	P
	6 1	0	1	0	6	0	0	1	6	P
	10 1	0	1	0	3	0	0	1	3	P
	22 1	0	0	0	0	0	1	0	1	F
	22 22	0	0	0	0	0	1	0	1	G
	24 2	0	0	0	0	0	0	0	0	F
	27 22	0	1	0	4	0	0	1	1	F
Mar.	5 22	0	0	0	0	0	0	0	0	F
	7 2	0	0	0	0	0	0	0	0	G
	7 22	0	0	0	0	0	0	0	0	P
	10 1	0	0	0	0	0	0	0	0	P
	12 23	1	0	5	0	0	0	1	5	G
	16 4	0	1	0	9	0	0	1	9	F
	24 2	0	1	0	2	0	1	1	3	P
	26 21	0	1	0	2	0	1	1	3	F
	28 22	0	1	0	2	0	1	1	3	G
	30 0	0	1	0	2	0	0	1	2	F
Apr.	3 3	0	2	0	6	0	0	2	6	G
	3 21	0	1	0	3	0	1	1	4	G
	5 0	0	1	0	2	0	1	1	3	G
	5 21	0	1	0	2	0	0	1	2	G
	7 2	0	1	0	2	0	0	1	2	F
	8 3	0	0	0	0	0	0	0	0	F
	10 3	0	1	0	2	1	1	1	4	G
	10 21	0	2	0	8	1	0	2	9	G
	12 22	0	2	0	11	0	0	2	11	G
	14 1	0	1	0	2	0	0	1	2	F
	17 2	0	2	0	6	0	1	2	7	G
	18 3	0	2	0	4	0	1	2	5	G
	19 22	0	0	0	0	1	0	0	1	P
	24 2	0	0	0	0	1	1	0	2	E
	24 22	0	1	0	2	1	0	1	3	G
	26 21	0	1	0	9	1	0	1	10	G
	28 1	0	1	0	16	0	0	1	16	G
May	1 1	0	1	0	2	0	0	1	2	E
		31	95	336	601	15	22	129	974	

These observations were made with a 7.1-inch refractor. The results tabulated indicate in each case groups and spots actually counted and drawn. A large Herschel Prism, with an eye-piece — power 55 — having a reticulated micrometer, and showing the entire disk of the sun, was used for the first plot and counting of spots. Later the details were further examined, and the count corrected by use of higher powers. The character of the definition was decided by the degree of distinctness of the granulations on the solar disc. E, G, F, P indicate respectively excellent, good, fair, poor definition.

The total number of different groups observed was 31, containing 321 different spots. 11 groups were north of the equator, co-

taining 129 spots, and 20 were south, containing 192 spots. There were also observed 10 isolated spots, 4 north and 6 south.

Of the groups whose latitude and longitude were obtained, 12 were within 10° of the equator; 9 between 10° and 20°; and only 1 above 20°. This group extended from —21° to —25°. One group was observed near the equator, Feb. 1, 1899, extending from 0° to —2°.

When an examination is made of the latitude and longitude of the spots observed during the seven months, some peculiar facts are at once noticed. With the possible exceptions of certain minor manifestations, there were no disturbances observed in north latitude between 0° and 180° of longitude, nor in south latitude between 270° and 360° of longitude. From Sept. 26 to Dec. 1, there were 121 different spots north of the equator, and 89 south; while from Dec. 1 to May 1, only 12 were north, 109 south.

There was but one case in which reappearance seemed surely proved. However, the plottings made Feb. 3 of a group having a mean latitude of —1° and longitude 91° 30′, when compared with those of Jan. 5, indicate a reappearance, but as no accurate determination of the position of the group was made in January, some uncertainty exists. On April 2 a normal spot was nearly central, with a mean latitude of —13°, longitude 59°. This appeared again April 23, and was central about April 29, having a mean latitude of —13°, longitude 60° 30′. The spot remained normal throughout each series of observations, but during its second appearance a number of pores developed.

As to the appearance of the penumbra of essentially symmetrical spots when near the limb, there were three cases in which the penumbra showed on the side away from the limb, and not on the side next the limb. Two cases showed penumbra on the side next the limb, and not on the side away from the limb. In three cases, showing penumbra on both sides, the penumbra was broader on the side next the limb; only one case in which the penumbra was broader on the side away from the limb. Nine spots had penumbra on all sides when near the limb, but with greatest extent north and south. There was one case in which a symmetrical spot lost its penumbra entirely when near the western limb, and three cases which developed penumbra soon after appearing on the eastern limb. No spot appeared as a projection, while two appeared as depressions on the limb.

The greatest maximum occurred Sept. 30, a total of 56 spots, 30 north of the equator, and 26 south. The next maximum was Nov. 3, 47 spots, 31 north and 16 south. Other maxima occurred Oct. 6, 28 spots, all south; Jan. 2, 23 spots, all south. There were four periods when no spots at all were visible, Dec. 13 to 16, Feb. 24, March 5 to 11, and April 8. On Oct. 20, Nov. 24, Jan. 20, Feb. 20, March 29, April 19, only one spot was observed.

NOTE ON THE POSITION OF ζ *HERCULIS*.

BY ERIC DOOLITTLE.

In computing the orbit of this star recently published (*A.J.* No. 460), no observations were available nearer periastron than 1897.60. The following additional observations are in the most critical part of the orbit.

	θ_o	ρ_o	n		DOBERCK $\theta_o-\theta_c$	DOOLITTLE $\theta_o-\theta_c$
	°	″			°	°
(1)1896.452	6.0	0.54	2	Lewis, 28-inch	— 1.0	—10.2
(1896.580	14.3	0.64	–	Comstock)	+ 9.3	— 2.0
(2)1897.404	2.3	0.46	3	Lewis, 28-inch	+27.7	+14.8
(3)(1897.600	344.2	0.66	3	Aitken, 12-inch)	+16.0	— 3.3
1898.664	287.4	0.53	6	Bryant, Bowyer, Lewis, 28-inch	+ 3.1	—14.4
(4)1899.177	271.7	0.52	1	Aitken, 36-inch	+ 2.0	—11.9
(5)1899.398	266.7	0.58	2–1	Doolittle, 18-inch	+ 4.6	—10.0

(1)(2) The yearly motion should be about 30°. (3) These observations throughout the computation (*A.J.* 460) were wrongly attributed to Mr. HUSSEY. (4) Mr. AITKEN has kindly sent me this measure; he writes, "Power, 1000; weight, 4; easier than last autumn." (5) Perfectly clear and separated from the disc. mean of eight measures on each night.

The observations are somewhat inconsistent, and measures during the coming summer are greatly to be desired.

The Flower Observatory, 1899 *June* 1.

THE THIRD CONFERENCE OF ASTRONOMERS AND ASTROPHYSICISTS.

The committee charged with the selection of a time and place for holding a third conference of astronomers and astrophysicists met in the City of Washington on February 8, 1899, and by unanimous vote of the members present, Messrs. NEWCOMB, MORLEY, HALE and COMSTOCK, resolved that such a conference should be held at the Yerkes Observatory early in the following September, the precise date to be subsequently determined by Professor HALE. In accordance with this resolution and at Professor HALE's invitation, the conference will be held at the Yerkes Observatory, Williams Bay, Wisconsin, beginning on Wednesday, Sept. 6, and closing on Friday, Sept. 8.

In its plan and scope this conference will be similar to those held in 1897 and 1898 at Williams Bay and Cambridge, accounts of which have been published elsewhere. The committee charged with perfecting a plan for the organization of a permanent society of astronomers and astrophysicists to have charge of future conferences will present its report at this time.

A circular giving information regarding local arrangements will be issued shortly.

GEORGE C. COMSTOCK, *Secretary*.

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ORBITS OF THE SATELLITES OF *MARS* FROM OBSERVATIONS MADE AT THE U.S. NAVAL OBSERVATORY AND THE LICK OBSERVATORY, 1894–6.

By STIMSON J. BROWN.

[Communicated by Prof. WM. HARKNESS, U.S.N., Astronomical Director.]

In the fall of 1894, I made a series of observations of *Deimos* and *Phobos*, with the intention of deriving, from the changes which had taken place in their orbits, a value of the ellipticity of *Mars*.

The orbits resulting from the observations of Professor HALL for the oppositions of 1879 and 1892, as well as my own for 1894, had been reduced and considerable progress made in the theory of the perturbations of the elements, when serious trouble with my eyes from over-use, obliged me to suspend all computing and nearly all observing for a year. Before I could again resume the subject, a paper was presented by Prof. HERMAN STRUVE (*Astr. Nach.*, Bd. 138), which was as complete and thorough a discussion of the whole subject as the available material admitted.

During the winter of 1896–7, the extensive series of CAMPBELL's 1894 observations of *Phobos* made with the Lick 36-inch equatorial, as well as my own and those of the Lick Observatory of both satellites at the opposition of 1896–7, were reduced and the orbits of the satellites derived. I had hopes that the new material would provide the means of decidedly improving STRUVE's theory, but its use showed that the changes would be insignificant, and that more time and more suitable and accurate observations would be necessary to reach any definitive results.

Since the recent publication in detail of STRUVE's elaborate investigation (*Mém. de l'Acad. Imp. de St. Petersbourg*, VIII *Ser.*, Vol. VIII, No. 3), an extended publication of my results would be superfluous. For the present, therefore, I merely offer here that portion of the work I have done on the subject and which is not contained in STRUVE's memoir.

Both satellites, and especially *Phobos*, are difficult objects with our 26-inch telescope, on account of the peculiar glare which surrounds the planet's image, extending beyond the orbit of *Deimos*. Except on rare occasions, it is not possible to observe the satellites with the planet in the field, without the use of some device for reducing the glare. Even with this, it is only at the two or three successive oppositions occurring near the perihelion of *Mars* that observations can be made sufficient in accuracy and number to permit a valuable derivation of their orbits. The larger telescopes, or those mounted in situations having more suitable atmospheric conditions, will have to secure the very important series occurring at the next few oppositions of *Mars*. The experience of Professor HALL at the oppositions of 1881 to 1888 is confirmed by my own during the last opposition, and that of Professor BARNARD at the Yerkes, where, I think, only one or two observations were secured on account of the unusually stormy winter weather.

The discussion of the observations shows also the importance of making all the observations of the satellites by measurements of rectangular co-ordinates referred symmetrically to the limbs of the planet. STRUVE adopted this plan in his 1894 observations with the 30-inch telescope at Pulkowa, with unquestionable advantage to his results so far as concerns systematic errors. All the measures with our 26-inch, and generally those of the position-angle at the Lick, have been made by estimating the center of the planet, and the results in both cases are generally affected with large probable errors and in some cases undoubted systematic errors in the elements dependent upon measures made in this way. This is even noticeable in the results of the three series into which the Lick Observatory observations for 1894 have been divided. Although the probable error of a single observation of the first series is unusually small, and the resulting value of a of greater weight than in any other series, yet some of the values seem to be affected by large systematic error. In this respect the results of my observations are in tolerably close agreement with the theory, while the values of a dependent upon measures of s referred to the estimated center of the planet are discordant.

The observations with the 26-inch equatorial were all made with an eye-piece, magnifying power 383, containing

a semi-circular piece of ruby glass for reducing the brightness of the planet. The illumination of the wires was secured by means of a small hand lamp, the rays of which were thrown through a small hole in the end of the micrometer-box opposite the micrometer-head. It is not, in my opinion, as convenient or efficient a method of illumination as the more modern electric appliances in use at the Lick and Yerkes Observatories, and which will be in the near future installed on our instrument.

The method of observing has been generally to measure four position-angles before and after the four measures of double distance, both referred to the estimated center of the planet's disk.

In the derivation of the computed places MARTH's well known formulas were used. The coefficients of the equations of condition for *Deimos* were computed for a "heterogeneous system of units," suggested by Professor NEWCOMB. I have not found the method convenient, nor well adapted to satellite-work, and have not used it in other computations. The formulas are given in Dr. HARSHMAN's article on the orbit of *Deimos*, (*A.J.* Vol. XIV, No. 331). As they are easily derived from MARTH's, which have recently appeared in this Journal (Vol. XIX, No. 441, p. 66), they are omitted. In using the formulas of MARTH, I have found it convenient to express r in terms of a, the mean distance assumed as unity, thus expressing all results in seconds of arc.

The Lick Observatory observations may be found in the *Astronomical Journal*, as follows:

CAMPBELL's, Vol. XV, No. 337, 1895.
SCHAEBERLE's, Vol. XVII, No. 399, 1896–7.
HUSSEY's Vol. XVIII, No. 424, 1897–8.

The grouping of the observations, in order to reduce the number of equations of condition, will be readily seen by comparing the times of the observation given in the tables below with those printed with the original observations.

In the Washington observations the column marked "correction" contains the correction to apply to the observed quantity for refraction and phase, and generally to reduce the observed distance to the time of the observed position-angle.

Deimos, 1894.

U. S. NAVAL OBSERVATORY. — BROWN.

Washington Date	Obs. p	Corr.	W.M.T.	Obs. s	Corr.	Wt.	C — O Δp°	C — O $\Delta s''$	Remarks
h m	°	°	h m	″	″		°	″	
Oct. 1 11 47.0	231.78	−0.07	11 47.0	74.26	−0.17	1.00	−0.25	−0.19	Faint and difficult
6 10 47.6	239.43	−0.03	10 47.5	69.38	−0.09	1.00	+0.26	−0.19	
10 9 37.5	224.02	−0.03	9 37.5	70.36	−0.02	0.70	−0.01	−0.72	Very faint and difficult
11 10 52.7	244.06	−0.02	10 52.0	62.52	−0.02	1.50	+1.00	+0.16	Seeing very good
15 9 14.75	229.78	−0.01	9 15.0	74.20	0.00	2.00	+0.26	+0.62	" " "
11 38.25	218.96	−0.01	11 39.0	62.98	+0.02	2.00	+0.22	+0.14	Seeing excellent
13 38.9	203.23	−0.02	13 35.5	44.66	+0.00	2.00	+0.22	+0.16	" "
16 10 50.75	252.58	−0.01	10 51.5	52.05	+0.03	0.70	+0.55	+0.96	Very poor, very faint
17 9 10.5	38.03	+0.01	9 13.0	61.51	+0.03	1.50	+0.24	+0.13	Poor
10 36.25	27.89	+0.01	10 35.0	49.35	+0.07	1.50	−0.15	−0.42	Better image
18 9 31.75	64.17	+0.02	9 33.0	63.38	+0.04	2.00	+0.82	+0.68	Images good
11 34.4	54.84	+0.01	11 35.5	73.16	+0.02	2.00	+0.68	+0.59	" "
12 45.0	49.76	+0.01	12 48.0	74.33	+0.03	2.00	+1.00	+0.22	" "
19 8 49.5	198.34	−0.02	8 51.0	39.72	+0.07	2.00	−0.26	+0.27	" "
10 1.35	175.16	−0.01	10 1.5	28.91	+0.15	2.00	−0.26	+0.38	" "
10 36.0	158.34	−0.01	. . .	. .	. .	0.25	−0.56	. .	One setting near conjunction
20 8 38.3	236.57	+0.01	8 38.8	73.09	+0.03	2.00	+0.50	−0.32	Excellent seeing
10 33.6	228.77	0.00	10 35.5	73.12	+0.03	2.00	+0.39	+0.33	" "
24 9 6.8	206.71	+0.01	9 7.5	47.39	+0.04	1.00	−0.16	+0.14	Seeing poor
25 8 37.1	242.08	+0.01	8 37.5	66.41	+0.05	1.00	+0.58	−0.02	Seeing poor, clouds
27 10 5.0	44.42	−0.01	. . .	. .	. .	0.50	+0.11	. .	Clouded over
31 8 9.1	19.79	−0.08	8 11.0	39.94	+0.08	1.00	−0.18	+0.77	Fair
Nov. 1 7 41.5	60.04	±0.00	7 43.0	66.61	−0.05	2.00	+0.48	+0.25	
9 3.8	53.63	−0.01	9 4.0	69.92	−0.05	2.00	+0.61	+0.05	
10 26.8	47.24	−0.02	10 27.5	67.89	−0.06	2.00	+0.82	+0.39	
12 1.2	39.39	−0.03	12 1.0	60.36	−0.05	2.00	+0.59	+0.33	
6 10 0.2	54.88	−0.02	9 59.0	66.28	−0.13	1.50	+0.10	+0.90	
11 12.5	48.72	−0.04	11 12.0	65.92	−0.12	1.50	+1.10	+0.66	
12 56.6	40.67	−0.06	12 53.5	58.24	−0.10	1.50	+0.53	+1.65	Very faint
15 8 11.2	42.85	−0.11	8 20.0	58.18	−0.23	0.00	+2.29	−0.21	Almost invisible
20 8 15.4	50.20	−0.10	8 30.3	56.98	−0.27	0.50	+0.46	+1.09	" "
22 8 11.25	215.36	+0.24	8 33.8	45.50	+0.31	0.50	+1.23	−0.34	" "

ASSUMED ELEMENTS OF *Deimos*.

Oct. 24.0 G.M.T.	u 142°.35		Oct. 24.0 G.M.T.	a 32″.509
	J 38°.012			n 285°.162
	N 48°.017			e 0.0000

NORMAL EQUATIONS.

ΔJ	ΔN	Δu	Δa	ξ	η	n
38.278	+17.199	+16.861	+ 6.912	+ 0.409	+ 6.791	−15.148
	37.692	+33.425	− 2.135	−13.333	− 28.870	− 1.423
		37.175	− 11.808	−10.725	− 28.370	− 7.854
			163.727	− 4.167	+ 0.421	+23.133
				48.961	+ 50.162	− 9.635
					150.827	− 9.989
					$[nn]$	25.181

The solution of the normal equations give these corrections:

ΔJ	$+0°.4153$	$\pm$ 0°.0454
ΔN	$-0°.6569$	$\pm$ 0°.0914
Δu_0	$+0°.6243$	$\pm$ 0°.1001
Δa	$-0″.1214$	$\pm$ 0″.0198
ξ	$+0°.0916$	$\pm$ 0°.0431
η	$+0°.0479$	$\pm$ 0°.0251
r_1	$\pm 0°.239$ or $\pm$ 0″.135	for one observation of weight unity.

$[nn]$ 6 = 10.297
$[vv]$ p = 10.627

The corrected elements for the mean epoch Oct. 24.78 G.M.T. referred to the apparent equator:

u_0 142°.974 Oct. 24.0 G.M.T.		a 32″.3876
J 38°.457		π 27°.59 $\pm$ 16°.6
N 47°.390		e 0.001803 $\pm$ 0.000697

Deimos, 1896.

U. S. NAVAL OBSERVATORY. — BROWN.

Washington Date	Obs. p	Corr.	W.M.T.	Obs. s	Corr.	Wt.	C − O Δp	C − O $\Delta s''$	Remarks
	°	°	h m	″	″			″	
Nov. 18 12h 16m.2	239.52	−0.06	12 38.2	52.53	−0.19	½	+1.17	−0.37	Fair
22 9 32.0	241.65	−0.02	9 51.2	55.93	−0.12	1.00	−0.69	−0.65	Seeing good
10 23.4	241.98	−0.03	10 29.4	54.23	−0.12	1.00	−0.84	+0.18	
11 0.0	241.94	−0.03	11 10.6	51.82	−0.12	1.00	−0.67	−0.11	
11 59.5	241.79	−0.04	12 21.7	44.16	−0.12	1.00	−0.27	+0.48	
13 2.1	242.57	−0.05	12 45.3	41.08	−0.12	1.00	−0.72	+0.60	
. . .	. .	. .	13 23.5	35.73	−0.10	1.00	. .	+0.55	
25 10 2.2	60.85	+0.06	10 25.0	50.09	+0.11	1.00	−0.74	−0.43	Seeing poor, weather thick
Dec. 9 11 15.5	57.84	0.00	11 3.8	55.62	+0.01	1.00	−0.64	−0.35	Fair
12 14.2	56.24	0.00	12 27.0	48.22	+0.01	1.00	+0.33	+0.51	
12 45.5	56.96	0.00	. . .	.	. .	1.00	−0.79	. .	
11 9 15.8	236.85	+0.01	9 23.0	51.41	+0.02	1.00	−0.54	−0.26	Good seeing
10 30.5	235.51	0.00	10 41.2	43.30	+0.01	1.00	−0.28	−0.72	Excellent
11 25.7	234.98	0.00	11 15.2	37.25	0.00	1.00	−0.91	+0.70	
12 14.0	. .	. .	12 14.0	27.95	+0.01	1.00	−0.14	+0.55	
14 9 39.8	58.27	−0.05	9 54.5	56.10	+0.01	1.00	. .	−0.70	Fair
16 7 59.0	237.66	+0.02	8 16.0	55.51	+0.02	1.00	−0.59	+0.49	Fair
9 29.2	235.91	−0.01	9 41.5	52.44	+0.02	1.00	−0.08	+1.02	
11 10.0	234.76	−0.01	11 21.5	44.53	+0.02	1.00	−0.66	+0.15	
23 8 20.5	54.86	−0.02	8 38.2	50.93	−0.01	1.00	−0.62	−0.86	
9 30.0	53.50	−0.05	9 18.0	47.12	−0.04	1.00	−0.79	−0.26	
28 7 52.6	56.14	−0.09	8 12.6	52.79	−0.09	1.00	−0.75	−0.91	Faint
8 30.0	54.83	−0.07	8 42.2	51.83	−0.09	1.00	−0.24	−0.66	Much better
9 48.1	53.20	−0.08	9 39.4	48.93	−0.10	1.00	−0.32	−0.61	" "

Assumed elements:

J	38°.457	
N	47°.39	
u_1	192°.21	Dec. 1.0 G.M.T.
r_0	32″.321	
n	285°.162	

The resulting normal equations, using the weights given above, except the equations in s double weight, are as follows:

ΔJ	ΔN	Δu_0	ξ	η	Δa	n
7.642	+ 5.679	+ 0.537	+ 0.468	− 0.585	+ 0.335	+ 5.156
	14.885	+ 8.500	+ 5.887	− 9.922	−15.746	+ 4.428
		10.296	+ 7.755	−12.706	−20.926	− 2.510
			16.088	−26.885	− 6.601	− 7.917
				54.308	+15.827	+14.646
					99.974	− 6.390
					nn	23.092

From the solution of the normal equations resulted the following corrections, and corrected elements, for the mean epoch Dec. 9.1 G.M.T., and to the apparent equator of that epoch:

ΔJ	−0°.2641 ± 0°.152		J	38°.19	± 0°.15	
ΔN	−0°.672 ± 0°.151		N	46°.72	± 0°.16	
Δu	+0°.915 ± 0°.221		u	193°.12	± 0°.22	Dec. 1.0 G.M.T.
Δa_0	+0″.189 ± 0″.0457		l	239°.84	± 0°.26	
ξ	−0°.0734 ± 0°.215		a	32″.510		
η	−0°.2726 ± 0°.105		$[vv]$	12″.21		
π	195°.63		$[nn6]$	11.84		
e	0.00194		r_1	±0°.308 or ±0″.174		

Deimos, 1896.

Lick Observatory. — Schaeberle.

Greenwich Mean Date	Computed p	Observed p	C − O	Computed s	Observed s	C − O	Residuals r_p	Residuals r_s	$\sqrt{p}$ Weight
h m	°	°	°	″	″	″	°	″	
Nov. 28 17 49.2	240.17	240.70	−0.53	40.16	41.74	−1.58	−0.04	−0.55	1.16
18 6.9	240.14	241.50	−1.36	42.58	44.00	−1.42	−1.02	−0.42	1.16
18 25.1	240.11	241.14	−1.03	44.92	45.80	−0.88	−0.74	+0.17	1.30
18 57.5	240.08	241.62	−1.54	48.63	49.93	−1.30	−1.57	−0.57	1.42
19 24.8	240.04	240.00	+0.04	51.28	52.36	−1.08	+0.66	−0.40	1.42
19 49.0	240.01	240.40	−0.39	53.25	53.84	−0.59	+0.02	+0.18	1.42
20 14.0	239.99	239.73	+0.26	54.89	54.61	+0.28	+0.65	+0.87	1.00
20 33.5	239.98	240.23	−0.25	55.89	55.55	+0.34	+0.14	+0.83	1.00
20 51.0	239.95	240.27	−0.32	56.56	56.20	+0.36	+0.05	+0.77	1.00
21 10.2	239.93	240.05	−0.12	57.07	57.06	+0.01	+0.25	+0.32	1.00
21 13.3	239.90	239.40	+0.50	57.36	58.25	−0.89	+0.52	−0.75	0.60 1.00
21 58.0	. .	. .	. .	57.24	57.77	−0.49	. .	−0.42	1.00
22 9.5	. .	. .	. .	57.05	57.05	0.00	. .	0.00	1.00
22 18.0	239.86	240.10	−0.24	. .	. .	. .	+0.06	. .	0.60
22 25.0	. .	. .	. .	56.64	56.97	−0.33	. .	−0.39	1.00
22 36.7	. .	. .	. .	56.23	56.92	−0.69	. .	−0.68	0.60
22 41.7	239.84	239.40	+0.44	. .	. .	. .	+0.45	. .	0.60
22 51.2	. .	. .	. .	55.59	56.12	−0.53	. .	−0.48	0.60
23 5.0	. .	. .	. .	54.86	54.93	−0.07	. .	−0.40	1.00
23 25.5	239.79	240.10	−0.31	. .	. .	. .	−0.01	. .	0.60
23 36.3	. .	. .	. .	52.72	53.14	−0.42	. .	−0.83	1.16
Dec. 4 17 55.5	57.20	58.45	−1.25	38.19	37.14	+1.05	−1.04	+0.69	1.00
5 21 31.2	58.16	57.37	+0.79	55.15	55.22	−0.07	+1.13	−0.20	1.00
21 46.0	58.06	57.87	+0.19	54.23	54.02	+0.21	+0.52	+0.06	1.00
22 3.5	57.93	58.47	−0.54	52.96	53.09	−0.13	−0.22	−0.27	1.00
22 12.2	57.85	58.30	−0.45	52.25	52.34	−0.09	−0.14	−0.25	1.00
22.4	57.79	57.80	−0.01	51.36	51.92	−0.56	+0.29	−0.73	1.00
22 36.6	57.67	57.13	+0.54	50.02	50.25	−0.23	+0.84	−0.42	1.00
22 51.3	57.55	57.30	+0.25	48.50	48.45	+0.05	+0.33	−0.10	0.60
23 15.9	57.32	57.10	+0.22	45.69	45.22	+0.47	+0.26	+0.14	0.60
23 22.0	. .	. .	. .	44.94	44.49	+0.45	. .	+0.20	1.00
10 16 47.1	61.30	61.40	−0.10	35.19	35.80	−0.61	+0.48	−0.57	1.00
17 1.2	61.03	60.80	+0.23	37.34	38.20	−0.86	+0.79	−0.86	1.00
17 18.2	60.50	60.43	+0.07	41.13	40.14	+0.99	+0.61	+1.00	1.00
19 17 31.3	55.95	56.63	−0.68	54.85	56.26	−1.41	−0.26	−1.43	1.00
17 46.4	55.71	56.30	−0.59	54.48	55.51	−1.03	−0.17	−1.09	1.00
18 2.9	55.44	56.11	−0.67	53.90	53.56	+0.34	−0.25	+0.29	1.00
18 28.5	55.00	56.23	−1.23	52.66	52.35	+0.31	−0.85	+0.24	1.00

The assumed elements for the computed places are the same as in the Washington series, except u_0, which is $u_0 = 192.41$ for Dec. 1.0 G.M.T. The resulting normal equations are as follows, the equations in s being given double weight.

ΔJ	ΔN	Δu_0	ξ	η	Δr	n
28.437	+ 5.786	+ 0.583	+ 0.913	+ 0.421	− 0.225	+11.898
	15.499	+12.360	− 9.868	+11.119	+ 3.849	− 7.326
		15.417	−13.124	+13.940	+ 4.769	−13.538
			59.239	−49.419	− 32.959	+28.342
[nn 6] 36.55				61.023	+ 0.057	−17.581
[vv] 36.21					185.640	25.417
					[nn]	62.386

The following corrections and corrected elements are derived from their solution, referred to equator of Dec. 4.4, 1896:

ΔJ	$-0^\circ.3665 \pm 0^\circ.0973$	J	$38^\circ.09 \pm 0^\circ.097$	
ΔN	$-0^\circ.2129 \pm 0^\circ.2196$	N	$47^\circ.18 \pm 0^\circ.220$	
Δu_0	$+0^\circ.8672 \pm 0^\circ.2231$	u_0	$193^\circ.28 \pm 0^\circ.223$	Dec. 1.0 G.M.T.
Δr_0	$+0''.0081 \pm 0''.0414$	r_0	$32''.329 \pm 0''.041$	
ξ	$-0^\circ.6227 \pm 0^\circ.1266$	π	$210^\circ.90$	
η	$-0^\circ.3730 \pm 0^\circ.1226$	e	0.01267	
$r_1 =$	$\pm 0^\circ.4701$ or $0''.2653$			

Observations of *Phobos*, 1894. — U. S. Naval Observatory. — Brown.

Wash. Mean Date	p°	Corr.	W.M.T.	s''	Corr.	Wt.	C − O $s.\Delta p$	C − O Δs	r_p	r_s	Remarks
h m	°	°	h m	"	"		"	"	"		
						1.33					
Oct. 1 12 59.5	55.28	+0.17	13 11.5	28.49	+0.16	2.00	+0.12	+0.67	+0.09	+0.60	Clouds
13 24.0	50.14	+0.14				0.33	−0.18		+0.02		
						1.00					
6 11 16.5	241.56	−0.11	11 30.5	28.13	−0.08	1.50	−0.03	+0.51	−0.32	−0.26	
11 40.5	234.18	−0.14				1.00	+0.43		+0.28		
						1.33					
11 10 14.0	56.04	+0.04	10 23.0	29.78	+0.06	2.00	−0.10	+0.06	−0.11	−0.04	Sat. very distinct
10 30.5	53.13	+0.05				1.33	−0.78		−0.65		
						0.67					
14 11 10.0	232.74	−0.01	11 21.5	29.40	+0.02	1.00	−0.18	+0.37	−0.28	−0.03	Faint
11 33.0	226.85	−0.02				0.67	−0.24		−0.16		
						1.33					
15 9 31.5	241.74	−0.02	9 13.5	27.43	−0.03	2.67	+0.35	+1.04	0.00	+0.22	
9 54.0	235.62	−0.02				1.33	+0.17		+0.01		Image good and
						1.33					seeing excellent
15 10 31.0	226.42	−0.02	10 41.0	26.97	+0.03	2.67	−0.14	+0.31	−0.08	+0.32	
10 52.0	220.60	−0.03				1.33	−0.47		−0.21		
						0.67					
17 8 11.0	231.08	+0.01	8 23.0	28.69	+0.07	1.33	−0.48	+0.10	−0.52	−0.12	Poor — faint
8 35.5	223.99	0.00				0.67	−0.35		−0.20		
						1.33					
18 10 3.0	66.72	0.00	10 13.0	25.80	−0.03	2.67	−0.12	+0.69	−0.26	+0.11	Seeing excellent
10 21.0	59.82	0.00				1.33	+0.24		+0.16		
						1.33					
18 10 55.5	52.02	0.00	11 3.5	29.34	+0.03	2.67	−0.62	−0.06	−0.43	+0.23	Seeing excellent
11 11.5	46.82	0.00				1.33	−0.19		+0.17		
						1.33					
18 11 52.5	33.73	0.00	12 3.0	19.01	+0.13	2.67	−0.98	−1.07	+0.04	−0.20	Seeing excellent
12 13.0	20.40	0.00				1.33	−1.19		+0.24		
12 23.5	13.80	0.00				0.33	−2.30		−0.66		Very close to planet
						1.33					
19 9 10.5	63.36	+0.01	9 19.5	27.42	+0.04	2.67	+0.39	−0.11	+0.26	−0.60	Seeing fine
9 28.5	57.72	+0.01				1.33	+0.40		+0.36		
						1.33					
20 8 4.5	65.41	+0.01	8 12.5	26.10	+0.06	2.67	−0.56	+0.76	−0.69	+0.26	Seeing excellent
8 19.0	58.77	+0.01				1.33	+0.36		+0.33		
						1.67					
20 9 3.5	47.68	+0.01	9 13.5	28.22	+0.04	3.33	−0.24	−0.69	+0.09	−0.14	Seeing excellent
9 23.5	42.78	+0.01				1.67	−0.83		−0.21		
10 17.0	10.00	0.00				0.42	−1.20		+0.41		
						0.67					

Wash. Mean Date			p	Corr.	W.M.T.	s''	Corr.	Wt.	C − O $s.\Delta p''$	C − O $\Delta s''$	r r_p	r r_s	Remarks
		h m		°	h m	″	″		″	″	″	″	
Oct.	24	8 29.0	230.66	0.00	8 39.5	28.61	+0.06	1.33	+0.22	−0.15	+0.17	−0.36	Poor
		8 49.0	225.22	0.00				0.67	+0.04		+0.13		
		9 35.5	206.28	0.00				0.67	−0.59		−0.02		
								1.00					
	31	8 42.0	232.87	−0.02	8 53.0	27.91	0.00	1.50	+0.40	−0.13	+0.38	−0.41	Poor
		9 3.5	226.88	−0.03				1.00	+0.37		+0.41		
								1.33					
Nov.	1	11 21.0	55.38	0.02	11 32.5	28.02	−0.03	2.67	+0.70	−0.18	+0.75	−0.11	Fine seeing
		11 43.0	50.00	−0.03				1.33	−0.16		+0.09		

The assumed elements of the orbit were

J 38°.012
N 48°.047
u 50°.37 Oct. 18.0 G.M.T.
r_0 12″.930
n 1128°.84425

The computed places and the coefficients of the equations of condition were computed from Marth's formulas. The normal equations, using the weights assigned in the above table (the first number in the lines having two, corresponding to the equation in p), are

Δu	ΔN	ΔJ	ξ	η	Δr_0	n
						″
50.7049	+34.9937	+ 52.8743	+ 0.6638	+10.1136	− 0.4881	+19.5625
	36.7362	+ 28.1750	+ 2.5489	+ 5.5432	+ 4.8811	+21.0320
		139.0327	− 3.9065	+11.4695	+ 2.0648	+ 5.4521
			64.0204	+ 9.6717	− 28.8121	+11.6097
$[nn]$ 6 7″.15				26.6661	− 3.4118	+ 8.6920
$[vv]$ 7″.23					159.3352	+10.1839
r_1 ± 0″.249						$[nn]$ = 23.3474

Their solution gives the following corrections to the elements assumed and the corrected elements referred to the mean equator and equinox of the Epoch Oct. 18.04 G.M.T.

Δu_0 −0″.1565 ± 0″.074	u_0 49°.68 ± 0°.330 Oct. 18.0 G.M.T.
ΔN −0″.4717 ± 0″.074	N 45°.95 ± 0°.327
ΔJ +0″.1269 ± 0″.028	J 38°.58 ± 0°.125
ξ −0″.1652 ± 0″.034	a 12″.845 ± 0″.021
η −0″.1741 ± 0″.052	π 223°.51 ± 10°.4
Δa −0″.0852 ± 0″.021	e 0.00907 ± 0.00171

Lick Observatory. — *Phobos*, 1894. — Campbell.

G. M. Date	Obs. p	Comp. p	C − O $s.\Delta p''$	v''	G. M. Date	Obs. p	Comp. p	C − O $s.\Delta p''$	v''
h m			″		h m			″	
Oct. 5 20 51.3	71.02	71.15	+0.05	−0.15	Oct. 12 21 37.4	62.06	62.15	+0.04	−0.18
55.7	69.00	69.05	+0.02	−0.14	40.4	60.96	61.20	+0.11	−0.10
9 21 34.2	231.41	231.54	+0.07	+0.34	43.2	59.85	60.34	+0.24	+0.04
37.3	231.20	230.76	−0.23	+0.05	22 0.0	55.23	55.70	+0.24	+0.12
22 11.5	222.09	221.39	−0.32	+0.16	2.3	54.60	55.09	+0.25	+0.15
14.9	221.22	220.25	−0.43	+0.07	51.9	42.55	41.66	−0.41	+0.02
35.7	213.27	211.62	−0.60	+0.08	56.2	41.37	40.65	−0.33	+0.16
40.5	210.92	209.00	−0.65	+0.08	23 0.5	39.78	38.68	−0.48	+0.09
44.3	209.49	206.60	−0.93	−0.17	16 22 40.7	219.75	217.93	−0.78	−0.22
10 23 37.5	63.19	63.63	+0.20	−0.03	43.1	218.72	216.97	−0.73	−0.15
40.8	61.84	62.53	+0.32	+0.10	46.7	217.22	215.48	−0.70	−0.11
45.1	60.90	61.18	+0.13	−0.08	23 2.9	210.28	206.90	−1.12	−0.42

SECOND SET.

G. M. Date h m	Obs. p	Comp. p	C − O $s.\Delta p''$	v''
Oct. 25 15 48.6	62.51	61.50	−0.18	−0.38
50.3	62.37	60.95	−0.67	−0.57
16 50.1	44.31	43.44	−0.40	+0.23
52.0	43.65	42.81	−0.39	+0.25
57.7	41.59	40.80	−0.35	+0.36
59.3	41.09	40.22	−0.38	+0.35
17 12.1	19.17	14.60	−1.21	+0.35
43.9	17.05	12.69	−1.12	+0.19
19 5.1	257.40	255.22	−0.78	−0.17
11.1	253.55	252.07	−0.57	−0.05
27 17 6.4	252.76	252.13	−0.24	+0.28
8.9	251.18	250.92	−0.10	+0.37
12.2	249.34	249.47	+0.06	+0.51
18 46.3	220.24	219.13	−0.47	−0.10
49.9	218.98	217.69	−0.53	−0.13
53.7	217.65	216.04	−0.68	−0.27
57.4	216.10	214.37	−0.67	−0.25
19 1.5	214.31	212.35	−0.73	−0.28
20.2	202.76	200.06	−0.78	−0.23
Nov. 2 14 45.9	71.44	70.47	−0.38	−0.34
50.5	69.89	68.46	−0.58	−0.54
18 10.2	267.91	266.62	+0.37	+0.51
13.4	263.97	263.15	+0.25	+0.54
19 6.7	240.04	239.06	+0.46	−0.16
10.9	238.59	237.77	+0.39	−0.11

THIRD SET.

G. M. Date h m	Obs. p	Comp. p	C − O $s.\Delta p''$	v''
Nov. 6 22 3.0	253.26	251.67	−0.59	−0.02
7.8	250.95	249.50	−0.56	−0.07
9 15 3.8	75.14	73.10	−0.72	−0.60
7.4	73.86	71.38	−0.72	−0.61
55.1	54.47	51.47	0.00	+0.08
59.0	53.16	53.32	+0.07	+0.17
16 24.5	46.30	45.30	−0.43	−0.17
27.7	44.41	44.18	−0.10	+0.18
17 5.5	28.75	26.58	−0.67	+0.23
11.5	25.10	22.34	−0.79	+0.20
13 15 28.2	236.71	236.69	−0.01	+0.08
31.1	234.93	235.42	+0.21	+0.27
16 5.3	224.23	224.98	+0.31	+0.27
8.7	222.69	223.79	+0.45	+0.10
19 57.6	41.44	44.04	−0.16	+0.12
20 0.8	43.80	42.86	−0.38	−0.06
14 13 43.4	252.80	252.53	−0.09	+0.18
47.0	250.31	250.73	−0.15	+0.35
15 42.3	209.21	206.80	−0.72	−0.69
19 34.3	27.74	25.22	−0.73	+0.14
37.6	25.53	22.87	−0.74	+0.19
21 40.3	246.78	245.10	−0.66	−0.35
44.7	244.59	243.48	−0.15	−0.16
58.6	239.83	238.80	−0.44	−0.29
22 0.0	239.16	237.70	−0.62	−0.50
22 13 48.1	236.22	236.40	+0.07	+0.15
51.2	234.98	235.40	+0.17	+0.23
17 23.3	60.39	61.11	+0.27	+0.34
26.9	58.93	59.91	+0.38	+0.44
44.0	53.61	54.42	+0.32	+0.41
59.3	49.36	49.57	+0.08	+0.23
18 3.3	47.86	48.28	+0.26	+0.41
18.3	43.64	43.51	−0.04	+0.24

FIRST SET.

G. M. Date h m	Obs. s	Comp. s	C − O $s.\Delta s''$	v''
Oct. 9 21 47.0	29.81	29.44	−0.37	−0.40
55.7	28.92	28.61	−0.31	−0.18
59.9	28.27	28.10	−0.17	+0.03
22 4.1	27.63	27.50	−0.13	+0.15
7.9	27.36	26.88	−0.46	−0.14
21.7	24.51	24.16	−0.35	+0.11
24.2	23.98	23.60	−0.38	+0.10
26.0	23.24	23.17	−0.07	+0.42
29.2	22.90	22.40	−0.50	0.00
30.7	22.36	22.00	−0.36	+0.15
10 23 20.4	21.22	21.84	+0.62	+0.05
22.4	21.96	22.35	+0.39	−0.16
25.5	22.44	23.10	+0.66	+0.15
29.3	23.74	23.98	+0.24	−0.22
32.9	24.39	24.79	+0.40	−0.01
12 21 47.5	28.00	28.26	+0.26	+0.14
49.4	28.40	28.49	+0.09	0.00
51.8	28.66	28.76	+0.10	+0.04
54.0	29.04	28.99	−0.05	−0.07
56.3	29.13	29.21	+0.08	+0.10
23 20.3	21.37	20.02	−1.35	−0.02
22.0	20.81	19.55	−1.26	+0.08
23.5	20.73	19.15	−1.58	−0.23
25.0	20.05	18.74	−1.31	+0.01
26.2	19.73	18.40	−1.33	+0.03
28.5	19.06	17.77	−1.29	+0.07
30.9	18.47	17.00	−1.47	−0.12
33.2	17.81	16.46	−1.35	−0.01
34.8	17.11	16.01	−1.40	−0.07

SECOND SET.

G. M. Date h m	Obs. s	Comp. s	C − O $s.\Delta s''$	v''
Oct. 25 15 54 7	27.84	27.73	−0.11	−0.08
59.4	28.30	28.20	−0.10	0.00
16 1.1	28.63	28.56	−0.07	+0.09
8.8	28.98	28.84	−0.14	+0.11
13.1	29.38	28.97	−0.41	−0.09
18.2	29.50	29.03	−0.47	−0.07
22.1	29.42	29.00	−0.42	+0.04
26.4	29.50	28.87	−0.63	−0.10
31.9	29.30	28.60	−0.70	−0.07
37.2	29.07	28.19	−0.88	−0.15
44.2	28.42	27.47	−0.95	−0.11
17 6.7	24.94	23.77	−1.17	+0.02
11.2	24.02	22.81	−1.21	+0.04
14.8	23.42	22.00	−1.42	−0.16
18.2	22.60	21.21	−1.39	−0.11
21.4	21.93	20.42	−1.51	−0.20
24.6	21.17	19.66	−1.51	−0.18
27.8	20.22	18.85	−1.37	−0.03
32.5	19.08	17.64	−1.44	−0.10
35.9	18.19	16.77	−1.42	−0.15
38.7	17.31	16.05	−1.26	−0.03
27 17 54.0	27.90	28.55	+0.65	+0.12
18 2.6	28.30	28.72	+0.42	+0.04
12.3	28.31	28.54	+0.23	+0.03
19.3	27.76	28.07	+0.31	+0.23
26.3	27.28	27.53	+0.25	+0.27
38.2	25.73	25.80	+0.07	+0.26
42.5	25.02	25.10	+0.08	+0.31
19 6.9	20.02	19.95	−0.07	+0.14

SECOND SET — *Cont.*

G. M. Date	Obs. s	Comp. s	C − O Δs"	r_o"
Oct. 27 19h 11m.1	19.01	18.92	−0.09	+0.12
16.1	17.92	17.68	−0.24	−0.03
Nov. 2 14 58.4	24.38	24.45	+0.07	−0.02
15 16.5	26.66	26.74	+0.08	+0.17
21.6	27.59	27.31	−0.28	−0.07
34.5	28.05	27.64	−0.41	−0.09
40.4	28.15	27.59	−0.54	−0.10
45.3	28.18	27.44	−0.74	−0.21
50.0	27.90	27.21	−0.69	−0.09
16 4.5	26.84	25.91	−0.93	−0.10
8.8	26.37	25.36	−1.01	−0.13
18 18.4	16.79	18.52	+1.73	+0.33
22.6	17.89	19.49	+1.60	+0.23
19 16.5	26.98	27.38	+0.40	−0.12
21.1	27.12	27.54	+0.42	−0.01
26.8	27.24	27.59	+0.35	+0.01
33.7	27.20	27.45	+0.25	0.00
40.1	26.79	27.15	+0.36	+0.20
46.9	26.63	26.62	+0.01	−0.07

THIRD SET.

G. M. Date	Obs. s	Comp. s	O − C Δs"	r_o"
Nov. 6 22h 45m.4	25.72	26.49	+0.77	+0.20
54.7	25.78	26.68	+0.90	+0.41
9 15 14.4	21.79	22.26	+0.47	+0.41
26.5	24.04	24.02	−0.02	0.00
37.1	25.19	25.14	−0.05	+0.08
45.7	25.84	25.73	−0.11	+0.12
16 6.2	26.36	26.03	−0.33	+0.21
16.1	26.10	25.38	−0.72	+0.08
17 16.8	16.95	15.19	−1.76	−0.36
19.8	16.40	14.54	−1.86	−0.47
10 14 49.3	26.29	25.72	−0.57	−0.26
15 1.2	26.17	25.75	−0.42	−0.05
18 40.5	25.16	25.72	+0.56	+0.08
49.0	25.30	25.74	+0.44	+0.07
58.1	25.13	25.43	+0.30	+0.05
Nov. 10 19 6.9	24.64	24.82	+0.18	+0.04
13 15 36.7	24.73	25.06	+0.33	−0.10
15 43.4	24.74	25.01	+0.27	−0.07
51.5	24.42	24.71	+0.19	−0.05
59.0	23.96	24.20	+0.24	+0.09
19 36.8	25.63	24.86	−0.77	−0.24
44.1	25.31	24.47	−0.84	−0.20
50.2	24.94	24.03	−0.91	−0.18
14 13 54.1	20.80	21.62	+0.82	−0.16
14 2.6	21.93	22.73	+0.80	−0.09
33.1	24.30	24.81	+0.51	+0.06
38.8	24.52	24.81	+0.29	−0.06
45.0	24.53	24.66	+0.13	−0.08
50.1	24.29	24.42	+0.13	−0.10
15 47.7*	16.22	15.96	−0.26	−0.02
51.5*	15.02	15.16	+0.14	+0.57
18 23.2	25.08	24.77	−0.31	+0.05
29.3	25.16	24.75	−0.41	+0.04
34.2	25.16	24.63	−0.53	−0.01
19 42.0	16.19	14.79	−1.42	−0.07
44.5	15.58	14.45	−1.13	+0.21
49.7	14.58	13.41	−1.17	+0.14
21 18.1	18.15	18.91	+0.76	−0.38
25.3	19.30	20.20	+0.90	−0.17
28.6	19.83	20.70	+0.87	−0.16
34.3	20.75	21.64	+0.89	−0.06
22 11.1	24.31	24.72	+0.41	−0.05
18.1	24.58	24.73	+0.15	−0.20
13 55.8	22.20	22.83	+0.63	+0.23
14 3.5	22.21	22.74	+0.53	+0.24
17 33.4	22.88	22.49	−0.39	−0.19
38.8	23.01	22.69	−0.32	−0.05
48.2	23.18	22.77	−0.41	−0.02
51.6	23.27	22.73	−0.54	−0.12
18 8.4	22.64	21.92	−0.72	−0.05
12.0	22.30	21.62	−0.68	−0.05

* Double weight.

NORMAL EQUATIONS. — LICK, 1894.

FIRST SET (to Oct. 16, inclusive). I.

ΔJ	ΔN	Δu_0	ξ	η	Δa	n
83.0474	+18.9368	+29.8105	− 1.0736	−14.1127	+ 9.8497	− 0.2180
	46.3843	+45.7077	− 8.5432	−18.6316	− 4.9542	+26.2907
		64.4348	+ 1.4870	−15.2061	− 20.3883	+32.3189
			19.1862	+15.6033	+ 6.0107	− 0.2079
				68.6337	− 22.3586	+ 8.6089
					96.1998	−18.0713
					[nn]	25.1831

[nn]6 1".30
[vv] 1".29
r_1 ± 0".1117

SECOND SET (Oct. 25 to Nov. 2 inclusive). II.

ΔJ	ΔN	Δu_0	ξ	η	Δa	n
62.0290	+15.0003	+19.5060	− 5.0283	− 3.1533	+ 16.1706	+ 6.4034
	41.0320	+40.2263	+ 3.0775	+ 8.7173	− 15.2178	+28.7607
		63.0342	+ 3.0548	+20.4797	− 31.1547	+40.5055
			23.8361	+24.7481	− 8.2114	+13.5636
				86.1605	− 29.4387	+40.7790
					184.1954	−28.4689
					[nn]	41.2315

[nn]6 3".72
[vv] 3".93
r_1 ± 0".1589

Third Set (Nov. 6 to 22 inclusive). III.

ΔJ	ΔN	Δu_0	ξ	η	Δa	n
76.5093	+15.3136	+29.0416	+ 6.2214	+ 4.2320	+ 7.2365	+ 0.2711
	26.7954	+27.4338	+ 7.6539	+ 7.7425	+ 1.4694	+14.8642
		46.3418	+ 4.6304	+11.0455	− 7.6365	+23.1704
$[nn]$ 6 5″.19			23.8038	+14.4689	+ 1.2408	+10.4463
$[vv]$ 6″.38				63.5689	+ 7.1632	+31.7178
r_1 ± 0″.1793					164.1808	− 2.7460
					$[nn]$	31.5557

Results of Solution.

	I	II	III
ΔJ	+0″.1249 ± 0″.013	+0″.2300 ± 0″.024	+0″.0506 ± 0″.022
ΔN	−0.3538 ± 0.043	+0.0584 ± 0.056	−0.2751 ± 0.042
Δu_0	−0.3682 ± 0.037	−0.5798 ± 0.047	−0.3728 ± 0.036
ξ	+0.1419 ± 0.042	−0.1684 ± 0.041	−0.1514 ± 0.040
η	−0.3103 ± 0.019	−0.3814 ± 0.025	−0.3022 ± 0.022
$a\Delta$	−0.0220 ± 0.016	−0.0036 ± 0.014	+0.0087 ± 0.013

Corrected Elements.

	I	II	III
	Oct. 11.8	*Oct.* 28.7	*Nov.* 13.5
J	38°.57 ± 0°.058	38°.24 ± 0°.099	39°.11 ± 0°.105
N	46°.48 ± 0°.192	46°.83 ± 0°.184	48°.39 ± 0°.250
u_0	48°.74 ± 0°.165	48°.72 ± 0°.159	47°.71 ± 0°.209
π	294°.08 ± 6°.80	243°.38 ± 6°.27	246°.19 ± 5°.98
e	0.01314 ± 0.00191	0.0103 ± 0.00102	0.01612 ± 0.00107
a	12″.908 ± 0″.016	12″.939 ± 0″.013	12″.926 ± 0″.014

Phobos, 1896.

Gr. Mean Date	Computed p	Observed p	C − O $s.\Delta p$	v	Gr. M.T.	Comp. s	Obs. s	C − O Δs	v	Weight Δp
			U.S. Naval Observatory — Brown.							
	°	°	″	″	h m	″	″	″	″	
Dec. 9 15 44.3	57.11	58.32	−0.46	−0.35	16 0.3	19.16	19.10	+0.06	−0.14	1.00
11 13 54.8	55.85	56.29	−0.15	−0.10	16 4.4	17.64	17.14	+0.50	+0.23	1.00
16 38.0	238.77	237.26	+0.57	+0.75	16 48.8	22.38	22.79	−0.41	−0.06	1.00
. . .	. .	. .	. .	. .	17 10.3	22.75	22.66	+0.09	+0.18	1.00
16 15 9.0	58.64	59.67	−0.37	+0.02	15 22.3	21.81	21.18	+0.63	+0.18	1.00
15 31.5	57.15	59.22	−0.81	−0.51	15 50.0	22.21	21.69	+0.52	+0.29	1.00
28 15 3.9	233.13	231.35	+0.67	+0.62	15 14.5	18.18	17.27	+0.91	+0.71	1.00
			Lick Observatory — Schaeberle.							
Nov. 28 22 59.6	239.90	240.00	−0.04	+0.12	22 59.6	22.99	23.25	−0.26	−0.05	1.00
23 16.9	239.83	. .	. .	. .	23 16.9	22.33	22.01	+0.32	+0.35	1.00
Dec. 4 16 25.0	239.27	240.34	−0.46	−0.27	16 25.0	22.37	22.71	−0.34	+0.08	1.00
16 41.3	238.93	239.68	−0.30	−0.16	16 41.3	23.08	23.70	−0.62	−0.11	1.00
17 1.3	238.52	238.60	−0.03	+0.03	17 1.3	22.40	22.83	−0.13	−0.43	1.00
17 17.9	238.13	238.31	−0.08	−0.11	17 17.9	20.56	20.92	−0.36	−0.46	1.00
19 54.5	59.74	61.68	−0.68	−0.35	19 54.5	19.97	19.25	+0.72	+0.07	1.00
20 4.2	59.49	61.90	−0.71	−0.39	20 4.2	21.33	20.67	+0.66	+0.05	1.00
20 17.4	59.19	61.28	−0.65	−0.37	20 17.4	22.57	21.20	+1.37	+0.86	1.00
10 17 44.9	238.67	238.77	−0.04	+0.14	17 44.9	21.94	22.02	−0.08	+0.37	1.00
18 2.2	237.98	238.75	−0.31	−0.20	18 2.2	22.87	23.12	−0.25	−0.04	1.00
19 15 50.7	238.44	238.67	+0.10	+0.28	15 50.7	20.20	20.92	−0.72	−0.22	1.00
16 4.1	237.49	236.86	+0.24	+0.35	16 4.1	21.52	22.16	−0.64	−0.29	1.00
16 19.6	236.54	235.90	+0.25	+0.32	16 19.6	22.09	22.65	−0.51	−0.10	1.00
16 35.3	235.55	235.33	+0.09	+0.11	16 35.3	21.70	22.10	−0.40	−0.42	1.00
16 51.6	234.43	234.32	+0.04	+0.01	16 51.6	20.24	20.26	−0.02	−0.21	1.00
17 5.1	233.33	. .	. .	. .	17 5.1	18.28	18.23	+0.05	−0.14	1.00

Gr. Mean Date	Computed p	Observed p	C — O $s.\Delta p$	r	Gr. M.T.	Comp. s	Obs. s	C — O Δs	r	Weight $\sqrt{p}$
			LICK OBSERVATORY — HUSSEY.							
	°	°	″	″	h m	″	″	″	″	
Dec. 20 18 45.4	57.79	57.40	+0.14	+0.51	19 0.1	21.82	21.69	+0.13	−0.23	1.00
19 52.4	52.99	53.02	−0.01	+0.09	. . .	. .	. .	. .	. .	1.00
										0.70
21 14 17.9	236.04	236.81	−0.30	−0.17	14 22.1	21.78	21.72	+0.06	+0.12	1.00
. . .	. .	. .	. .	. .	14 26.5	21.63	21.70	−0.07	−0.06	1.00
. . .	. .	. .	. .	. .	14 42.2	20.47	20.36	+0.11	−0.04	1.00
. . .	. .	. .	. .	. .	14 47.0	19.93	19.64	+0.29	+0.12	1.00
14 51.9	233.30	233.96	−0.22	−0.30	15 3.4	17.42	17.42	0.00	−0.17	1.00
. . .	. .	. .	. .	. .	15 8.1	16.58	16.34	+0.24	+0.04	1.00
. . .	. .	. .	. .	. .	15 12.2	15.76	15.38	+0.38	+0.18	1.00
. . .	. .	. .	. .	. .	15 17.4	14.67	14.54	+0.13	−0.05	1.00
										0.50
15 23.8	229.70	229.09	+0.14	−0.02	15 21.7	13.67	13.50	+0.12	0.00	1.00
										0.70
17 15.7	60.10	62.27	−0.66	−0.15	17 21.9	18.08	17.93	+0.15	−0.40	1.00
17 52.0	57.14	58.15	−0.38	−0.02	17 28.4	19.10	19.23	−0.13	−0.66	1.00
										0.70
18 7.4	56.02	56.97	−0.37	−0.06	18 20.2	21.41	21.42	−0.01	−0.08	1.00
. . .	. .	. .	. .	. .	18 29.8	20.65	20.35	+0.30	+0.13	1.00
. . .	. .	. .	. .	. .	18 52.3	17.55	17.50	+0.05	−0.09	1.00
18 57.5	52.00	52.72	−0.21	+0.46	19 1.9	15.71	15.57	−0.06	−0.22	1.00
20 58.3	240.94	241.25	−0.08	+0.08	21 7.7	17.42	18.50	. .	. .	1.00
21 31.3	237.78	238.16	−0.15	−0.02	21 40.1	21.36	21.51	−0.15	+0.16	1.22
. . .	. .	. .	. .	. .	21 50.0	21.76	21.73	+0.03	+0.18	1.22
. . .	. .	. .	. .	. .	21 57.1	21.81	21.54	+0.27	+0.44	1.22
. . .	. .	. .	. .	. .	22 17.9	20.77	20.87	−0.10	+0.45	1.22

The assumed elements are:

J 38°.46
N 47°.39
u_0 100°.60 Dec. 0.0 G.M.T.
r_0 12″.95

The equations of condition were given the weights assigned to the respective observations in the above table, all observations except a few of HUSSEY's position-angles having weight of unity. The resulting normal equations and corrections to elements are given below:

$a.\Delta J$	$b.\Delta N$	$c.\Delta u_0$	$d.\xi$	$e.\eta$	$f.\Delta r_0$	n''
						″
54.539	+21.936	+ 3.575	− 1.828	− 0.482	− 0.130	+ 7.010
	27.665	+16.349	+ 6.370	− 11.405	− 8.289	+ 1.423
		19.546	+ 6.613	− 14.311	− 10.217	− 1.262
			60.844	− 70.630	− 22.752	+12.402
				125.396	+ 39.779	− 7.622
					106.781	+ 3.203
					[nn]	12.147

From which

ΔJ	−0″.1895 ± 0″.040	J	37°.62 ± 0°.184
ΔN	+0″.1076 ± 0″.080	N	47°.87 ± 0°.367
Δu	+0″.0157 ± 0″.040	u_0	230°.56 ± 0°.186
Δa	−0″.0549 ± 0″.022	a	12″.895 ± 0″.022
ξ	−0″.4033 ± 0″.047	π	198°.91 ± 5°.0
η	−0″.1381 ± 0″.034	e	0.03305 ± 0.00370
		r_1	±0″.214
		[vv]	7″.02
		[nn]6	6.99

CONTENTS.

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OBSERVATIONS OF NEW AND OLD VARIABLE STARS IN THE SOUTHERN HEMISPHERE,

By R. T. A. INNES.

(Communicated by Dr. DAVID GILL, C.B., etc., H.M. Astronomer at the Cape of Good Hope.)

I forward herewith some results of observations of variable stars made here since 1896. The greater part of the working catalogue was originally taken from lists forwarded from time to time by Professor J. C. KAPTEYN arising out of his work on the *Cape Photographic Durchmusterung*. Some stars have been added from Dr. CHANDLER's Third Catalogue of Variable Stars, and a few are new.

Dr. GILL has arranged that the observations are to be printed in full detail in the *Annals* of the Cape Observatory.

110. *S Tucanae.*

C.P.D. −62°28. $0^h\ 17^m\ 10^s.9$, −62° 22′.0 (1875)

The variability of this star was announced from the Harvard Observatory in *Astr. Nachr.*. No. 3299, July, 1895. Observations from October, 1898, to March 17, 1899, indicate a maximum of

$9^M.1$ about Feb. 26, 1899.

The curve is very flat at maximum. No color noticeable. There are several faint stars so near that when the variable is under 10.5 visual magnitude, identification is difficult, but the star has been followed below 10^M.

146. *T Sculptoris.*

C.P.D. *nil.* $0^h\ 23^m\ 2^s.3$, −38° 35′.9 (1875)

A fair maximum, $8^M.6$, was secured about 1898 Oct. 24. We also have

M		
8.4	1872 Nov. 9	Cord. Z.C.
8.5	1889 Nov. 25	Cord. DM.
8.0	1897 Jan. 29	Cape.

These are fairly well represented by a period of 206.3 days.

In the 7-inch refractor the star is invisible at minimum for about one month. The form of the light-curve suggests that the minimum is about $11^M.7$.

1018. *R Horologii.*

C.P.D. *nil.* $2^h\ 49^m\ 40^s\pm$, −50° 23′.7± (1875)

A minimum of about $10^M.25$ occurred on Jan. 21, 1899. When too near the sun for further observation on May 22, 1899, the magnitude had risen to 7.3. Color = 7.3.

The curve is very flat at minimum, with a rapid rise towards maximum, *e.g.*:

M	
8.6	1899 May 10
8.0	12
7.3	19

C.Z. 2h1547.

C.P.D. −51°354. $2^h\ 56^m\ 52^s$, −51° 8′.2 (1875)

See C.P.D., Vol. I. List on page 93, No. 1.

An interpolated maximum occurred about April 13, 1899. We also have

M		
8.5	1872 Dec. 23	C.Z.
9.2	1887 Nov. 29	C.P.D.
8.1	1898 Jan. 29	Cape
7.9	Sept. 5	Cape

A period of 218.4 days is fairly exact.

In the 7-inch this star is invisible for 6 or 7 weeks. The rise and fall of this star form much the same sort of curve, an even one. The extrapolated minimum would be about $11^M.5$. Color = 4.0.

DM. −21°1019.

C.P.D. −21°694. $4^h\ 50^m\ 56^s.1$, −21° 24′.9 (1875)

As pointed out by Professor KAPTEYN (*A.N.* 2987) this star is variable.

Observations were begun too late this year to determine its period, which can only be a few hours.

The range is from $9^M.0$ to $10^M.0$.

Until further observations are secured, a few of those

already made will suffice to show the rapidity of light-change.

M			h m
9.1	1899 Feb. 26		
10.0	Feb. 27		
9.7	May 2	S.T.	9 4
9.3	2		10 1
9.1	2		10 26

The three last observations were recorded as good.

1803. *T Leporis.*

C.P.D. *nil.* $4^h 59^m 31^s$, $-22° 4'.4$ (1875)

Doubtful maxima were recorded about as follows:

M	
8.3	1897 Dec. 1
7.7	1898 Nov. 15

These with the epoch of Chandler's Third Catalogue and Thome's observation,

$8^M.75$ 1886 Oct. 27

indicate a period of 365.25 days, but there are inequalities. Color about 7.3.

Although very difficult to see at minimum, it is never quite invisible in the 7-inch.

1850. *S Pictoris.*

C.P.D. $-48°609$. $5^h 7^m 37^s$, $-48° 39'.6$ (1875)

The only visual observation of this star that is on record was made at Cordoba on Dec. 29, 1873, but it appears on 5 Cape Photo Plates between Nov. 22, 1887, and Nov. 19, 1895, and on 8 Arequipa Plates between Sept. 28, 1892, and Nov. 5, 1894.

It has been invisible in the 7-inch for the past few months.

A preliminary discussion of all the recorded apparitions furnishes a period of 423 days.

		M
C.P.D. Plates	1887 Nov. 22 and 29	9.0
	1890 Feb. 19	9.1
C. de C. Plate	1893 Dec. 8	10.4
Chart Plate	1895 Nov. 19	12±

Gilliss P.Z. 4619. (In no other Catalogue.)

$7^h 7^m 53^s$, $-72° 48'.9$ (1875)

This star is in a list of stars contained in Catalogues of Precision, but not found on the C.P.D. Plates.

Gilliss remarks, "Red, and sharply defined." $8^M.0$.

It is about 2′ s.f. Gilliss P.Z. 4616, which Gilliss calls "Blue and nebulous." $8^M.2$.

I looked up these stars on Jan. 13, 1899: — Both stars seen; No. 4616 is about $7^M.5$, and is yellow = 4 on Chandler's scale, and well-defined. No. 4619 is faint, say $10^M.6$. There is a 12^M 1′ N. of it.

It is therefore evident that Gilliss must have focussed on the red star, and by extreme contrast the neighboring *yellow* star appeared blue as well as being out of focus.

Gilliss P.Z. 4619 has brightened from $10^M.6$ on Jan. 31, 1899, to $9^M.35$ on May 25, and it is now losing brightness,— $9^M.55$ on June 3, 1899.

It is the reddest star I have seen, say 9.0 on Chandler's scale, and will probably never be photographed.

C.P.D. $-41°1681$.

$7^h 42^m 41^s.1$, $-41° 4'.0$ (1875).

This remarkable star is No. 8 of a manuscript "List of Suspected Variables" forwarded to this Observatory by Professor Kapteyn on August 27, 1895, but which only came into my hands on February last.

Of this star Professor Kapteyn says:

			M
"C.P.D. Plate	1046	1887 Dec. 17	9.3
	1055	Dec. 21	9.3
	2662	1890 May 9	9.3
	2667	May 10	10.2

No defect in the film of Plate 2667, nor in the image of the star can be detected."

I secured 37 observations between Feb. 14 and March 22, 1899, and 39 between April 23 and June 7, 1899. All these observations are well represented on the supposition that this star is an *Algol*-variable, period 12.91 days. The minima recorded are

		h m	M
1899 Feb. 14	Cape Sidereal Time	. .	10.5
Feb. 27	" " "	5 49	10.4
		7 53	10.6
Mar. 12	" " "	6 48	10.2
		7 19	10.3
May 13	" " "	10 22	9.5
		11 44	9.65
May 28	" " "	11 31	10.7

The descent and ascent would seem to be sudden, but further observations are required at the time of minimum, which must now be left over until the star rises at sunset. That this star is an *Algol*-variable seems quite certain, and if correct, this will be the longest period one.

A minimum was secured on June 10, viz.:

Cape Sid. Time		Cape Sid. Time	
h m	M	h m	M
11 7	10.75	13 49	10.2
11 27	10.65	13 57	10.1
12 11	10.7	14 9	10.0
12 43	10.65	14 11	9.9
13 0	10.45	14 14*	9.9
13 30	10.3	14 22*	9.85
13 41	10.3	14 28*	9.85

* Star low.

The middle time was probably passed before the observations commenced. If we assume that the number of periods since the C.P.D. Plate was taken (1890 May 10–

1899 June 10) to be 257 and the interval to be 3317.8 days the period will be

$$12^{d}.906 \pm 0^{d}.001$$

The visual range of magnitude is from $9^{M}.5$ to $10^{M}.7$.

C.P.D. −23°4672.

$9^h\ 39^m\ 16^s.3$, $-23°\ 26'.7$ (1875)

See *Astr. Nachr.*, Nos. 3426 and 3447.

No actual maximum of this star has been seen. When lost in the sun's rays last year (Aug. 4, 1898,) it was approaching a maximum. On drawing a curve through the plotted observations to that date it looks as if Aug. 5, 1898 would be about the actual epoch, and comparing the curve of 1898 with that drawn from recent observations a period of about 340 days is indicated. Using the date of the first C.P.D. Plate showing this star, viz.:

$8^{M}.75$ 1889 May 23

and the assumed maximum

$8^{M}.6$ 1898 Aug. 5

the interval is 3361 days. This suggests division by 10, and a period of about 336 days.

It will be some time before the descending curve can be drawn. The ascent to $9^{M}.7$ is steep; there is a rest of about a month before $9^{M}.5$ is attained, after that the ascent to $8^{M}.6$ takes about 20 to 30 days.

This star is invisible for 4–5 months at minimum in the 7-inch refractor.

C.P.D. −63°1243.

$9^h\ 54^m\ 50^s.5$, $-63°\ 17'.9$ (1875)

A new variable.

In the C.P.D. this star is recorded as $9^{M}.9$. It was invisible on Feb. 17, 26, 1899. At first sight it looked like an error in the C.P.D., as there was a star of about $9^{M}.6$ at $9^h\ 55^m\ 43^s \pm$, $-63°\ 17'.2 \pm$, which was not recorded in the C.P.D. Professor KAPTEYN kindly re-examined the Plate, and found both stars, the pr. star being the brighter. It is therefore undoubtedly variable, and is now under regular observations.

1899 May	10	9.5	1899 May 26	9.5
	11	9.15 red	31	9.6
	14	9.5	June 3	9.6
	19	9.55	6	9.7

C.P.D. −53°3515.

$10^h\ 10^m\ 35^s$, $-53°\ 51'.5$ (1875)

Announced as variable by Professor KAPTEYN in *Astr. Nachr.* No. 3389.

Visual observations:

1899 Feb. 20	$\overset{M}{9.1}$	red = 7
26	9.15	
Mar. 17	9.5	red = 7.5
21	9.55	
May 11	11.0	difficult to identify
27	<10	when so faint

Cor. D.M. −27°7724.

$10^h\ 45^m\ 22^s.2$, $-27°\ 58'.2$ (1875)

Not in C.P.D. See *A.N.*, No. 3441.

A maximum of this variable was undoubtedly secured at Cordoba as follows:

$8^{M}.2$ 1886 Mar. 4

Here we have

$\overset{M}{8.3}$	1897 Apr. 20	poor
8.45	1898 Mar. 30	good
8.4	1899 Feb. 23	fair

All these observations are suited by a period of 338.5 days.

In the 7-inch the star is visible for 6 mos.; the curve is fairly even both rising and falling — there is perhaps a little halt in falling, but it is uncertain at present. The apex of the curve is very sharp, so that maxima should be determined closely.

4056. *RS Centauri.*

$11^h\ 15^m\ 1^s$, $-61°\ 11'$ (1875)

Not in C.P.D. Found by Mrs. FLEMING.

I picked up this star accidently on Mar. 20, 1898, when it was $8^{M}.5$, reddish; it was then rapidly losing light. Further observations yielded maxima on

1898 Aug. 16	$\overset{M}{8.8}$
1899 Feb. 15	8.7

an interval of 182 days.

From Mar. 20 to Aug. 16, 1898 is only 148 days, so that it would appear that on Mar. 21, 1898 the maximum had been passed by 34 days, but it is more probable that the period has inequalities.

In the 7-inch the star is invisible for about a month. The rise and fall are both rapid. The curve seems to be irregular at maximum, probably however, due to errors of observation. Color = 7.

Cord. D.M. −32°8314. $8^{M}.5$.

$11^h\ 41^m\ 21^s.7$, $-32°\ 34'.5$ (1875)

This star does not occur in the C.P.D. It is certainly variable; observations here range from $8^{M}.9$ to $9^{M}.6$. The color is yellow, say 1.5 in CHANDLER's scale.

Good minima (which are the more strongly marked) were secured on

1898 April 27
1899 Mar. 13
May 4

These indicate a period of 53 days, but the accordance of all the observations is too indifferent to make this determination of much weight.

4935. *RT Centauri.*

$13^h\ 41^m\ 2^s$, $-36°\ 14'.2$ (1875)

The following maxima have been secured here:

M		Interval
8.1	1896 Aug. 25	
		247 days
8.9	1897 Apr. 29	
		502 days
7.9	1898 Sept. 13	
		243 days
8.2	1899 May 14	

Hence an average period of 248.0 days will represent the observations very well.

This star is generally visible at all parts of its curve in the 7-inch. It was, however, invisible at the minimum which occurred about Sept., 1897. Color = 7.5.

Ö.A. 13441.

$14^h\ 4^m\ 22^s.1$, $-28°\ 17'.6$ (1875)

This star does not occur in the C.P.D. [see C.P.D., Vol. 1, p. 75]. At present the maxima evidently take place when the star is too near the sun for observation, as on each of the following epochs the brightness of the star had been increasing and further observation was impossible:

M		O—C (d)
8.8	1898 Oct. 7	−3
8.8	1897 Sept. 24	−13
9.0	1896 Oct. 1	−2

Also

M			d
8.75	1879 June 29	Cordoba	−45
8.0	1851 May 20	Argelander	0

Assuming that Argelander's observation was made at a maximum and that the period is 368.3 days, the discordances are as in the last column.

No mention has been made of color, hence the star is probably whitish, but recently when bright enough for color observation it has been too near the sun.

This star is invisible for several months in the 7-inch. The curve is not regular, but if the above period is fairly approximate it will be about 30 years before the rise to and fall from a maximum can be fully secured.

Lac. 6417.

$15^h\ 26^m\ 58^s.5$, $-49°\ 5'.2$ (1875)

This variable has a double maximum and minimum, but the full period being about 510 days further observations will be required before all its peculiarities are known.

Recent observations indicate

	M	
Inferior min.	8.1	1897 May 24
Chief max.	6.9	Sept. 7
Chief min.	10.8	1898 Mar. 10
Inferior max.	7.4	July 20
Inferior min.	8.5	Oct. 15
Chief max.	7.3	1899 Jan. 25

Let us assume

Chief max. to chief min. =	120 days	Total 510 days
Chief min. to infer. max. =	205 days	
Infer. max. to infer. min. =	90 days	
Infer. min. to chief max. =	95 days	

This would show that the Cordoba observations of 1877.57 were taken at an inferior maximum; those of Aug.–Sept., 1876, at a chief maximum, the observation of Aug. 5, 1876, at an inferior minimum, and the Cape and Cordoba observations of June, 1876, at an inferior maximum. Further observations will show if these conclusions are correct. The color is about 7.5.

5752. *RZ Scorpii.* (*A.J.* No. 414).

$15^h\ 57^m\ 8^s$, $-23°\ 45'.2$ (1875)

Not in the C.P.D.

Maxima have been secured as follows:

M		
8.3	1896 May 20	poor
8.0	Oct. 10	poor
9.2	1897 Aug. 26	fair
8.8	1898 July 6	good
8.4	1899 May 17	poor

Introducing the Cordoba Zone observation

8.5 M 1873 June 13

as a maximum, all the observations will be fairly represented by a period of 155 days.

A fair minimum = 10^M was secured on July 28, 1896, but the star is generally invisible at minimum in the 7-inch. Color = 6.

Porter 2769.

$16^h\ 41^m\ 43^s$, $-19°\ 14'.3$ (1875)

The variability of this star is indicated in Vol. 1 of the C.P.D., page 93.

The star has been observed here since May, 1898. Maxima were secured as follows:

M	
8.5	1898 July 25
8.0	1899 May 3

and it may be assumed that the following observations were near the maximum:

M		
9.2	1888 Oct. 22	C.P.D.
8.5	1886 June 18	Porter

A period of 277 days is not inconsistent with these observations.

At minimum the star is invisible in the 7-inch. Color = 5 orange.

C.P.D. −35°7270.

$17^h\ 39^m\ 56^s.0$, −35° 39′.1 (1875)

The variability of this star has recently been announced (*A.J.* No. 464).

Maxima were recorded on

1898 July 24	$9^M.2$
1899 Apr. 30	9.0

These, with the C.P.D. observation of Nov. 3, 1890, indicate a period of 282 days.

The minimum magnitude recorded so far is about 10.6. Color = 6.

6901. *R Y Sagittarii.*

$19^h\ 8^m\ 24^s$, −33° 44′.4 (1875)

In 1898 June–Nov. this star was invisible.

In 1899 we have

May 19	$8^M.6$
May 27	8.7
June 6	9.0

This star has no simple period, indeed, so far there is no trace of any period whatever. Color, white, perhaps yellowish, perhaps reddish (3 obs.).

7122. *S Pavonis.*

$19^h\ 44^m\ 39^s.5$, −59° 30′.9 (1875)

This star is C.P.D. −59°7544; mag. = 9.2.

Observations indicate a very poorly determined maximum of about $7^M.5$ about Nov. 1, 1898.

By Dec. 13, 1898, it had faded to $8^M.3$, and on May 27, 1899, it was $8^M.7$. Color = 7.3.

7495. *S Indi.*

$20^h\ 47^m\ 7^s$, −54° 47′.9 (1875)

This star is C.P.D. −54°8772; mag. 8.6. It is remarked in a foot-note that the star appears on only 2 of 4 plates.

A very good maximum was secured on

1898 Nov. 1 $8^M.9$.

No color recorded.

Royal Observatory, Cape of Good Hope, 1899 June 13.

7685. *S Microscopii.*

$21^h\ 19^m\ 19^s$, −30° 23′.4 (1875)

See C.P.D., Vol. I, p. 82. No. 204.

A good maximum was observed as follows:

1898 Oct. 27 $8^M.1$

Color = 7.0.

To determine the period we have

1895 Nov. 7	$8^M.5$	Cape (Finley)
1897 Aug. 20	7.9	Cape and West (mean)

and the mean of Argelander's two observations June 30, 1849. These are all beautifully satisfied by a period of 217.1 days. Both rise and fall are rapid, but there is a halt before the minimum is attained. At minimum the star is just visible in the 7-inch, say about $11^M.5$.

8040. *S Gruis.*

$22^h\ 18^m\ 22^s$, −49° 4′.3 (1875)

This star does not occur in the C.P.D. It is reddish in color. Observations:

1898 Sept.	23	$7^M.5$
	28	8.0
Oct.	22	8.5 reddish
Nov.	1	8.9 red = 7.5
	29	9.8
Dec.	4	9.8
	13	10.5
	20	10.3
	31	11.0
1899 Jan.	15	11.5
	24	inv. (under $9^M.5$ at least)
May	3	inv. (good obs.)

The period is about 408 days.

8588. *R Phoenicis.*

$23^h\ 49^m\ 57^s.3$, −50° 28′.8 (1875)

Equal to C.P.D. −50°11883; mag. 9.0 (1889 Dec. 24). Observations:

1898 Oct.	15	$7^M.4$ color = 7
	22	7.6 color = 6
Nov.	30	10.0
Dec.	4	10.0
	14	10.5
	20	10.6
	31	10.8
1899 Jan.	15	11.5
	24	inv. (<10.0)

A period of 631 days will accord with the apparitions of 1872, 1884, 1889 and the above epoch, but this determination is of little value.

NOTES ON VARIABLE STARS, — No. 29,

BY HENRY M. PARKHURST.

Exclusion of Extremes. Photometric observations are peculiarly liable to extravagant errors from unnoticed clouds; which may be systematically excluded from affecting the remaining observations by adopting the principle of the exclusion of extremes. In determining the sky value, or line standard, instead of adopting the weighted mean of all the several extinctions, equal weights may be rejected from the two extremes. This principle seems to me a satisfactory mode of preventing abnormal errors from affecting the final results.

Smoothing the Curve. When two adjacent discordant observations are separated by a long interval from the preceding or following observations of the series, the light-curve will be less affected by a possible inaccuracy if the discordance is divided between them before smoothing the curve.

U Arietis. The intervals for the last two periods have been 374 and 352 days, showing a progressive diminution of 20 days, following the like increase before noted (*A.J.* 103), which had continued for three periods prior to my series. No apparent explanation.

RESULTS OF OBSERVATIONS.

No.	Star	Phase	Observed Date Julian	Observed Date Calendar	E	Corr.	W	Mag.	Factors			Remarks
				1898-99							d	
103	*T Andromedae*	Max.	4578.2	Oct. 15	9	+31	9	8.69	0.79	0.89	20	
419	*U Andromedae*	Max.	4581	Oct. 18	4	− 4	7	9.93	2.0	3.0	54	From elements *A.J.* 431
466	*U Piscium*	Max.	4633	Dec. 9	40	+ 2	5	11.17	1.0	1.7	26	
513	*R Piscium*	Max.	4623	Nov. 29	34	+ 4	9	8.67	0.94	1.89	31	
782	*R Arietis*	Max.	4611	Nov. 17	63	+11	7	8.39	1.44	1.32	28	
(857)	*— Ceti*	Max.	4606.0	Nov. 12	80	+0.2	6	9.01	0.23	0.34	8	
"	"	Max.	4641.2	Dec. 17	82	+0.6	6	8.77	–	–	–	
"	"	Max.	4675.6	Jan. 20	84	+0.2	6	8.61	–	–	–	Period 17.414 days
906	*R Trianguli*	Max.	4572	Oct. 9	11	− 7	8	5.96	0.73	0.77	17	
976	*T Arietis*	Max.	4662	Jan. 7	30	+23	9	8.22	4.75	3.25	33	Fluctuating
1113	*U Arietis*	Max.	4612	Nov. 18	6	+31	6	7.58	1.46	3.14	65	See note above
1166	*X Ceti*	Max.	4675	Jan. 20	4	− 3	9	9.60	1.82	0.93	18	From period *A.J.* 438
1577	*R Tauri*	Max.	4579	Oct. 16	41	− 8	1	8.80	–	–	–	
"	"	Max.	4632	Dec. 8	41	+45	1p	7.4	–	–	–	From a single observation
1582	*S Tauri*	Max.	4676	Jan. 21	38	−48	8	9.80	9.0	10.0	34	Curve too flat for accuracy
1717	*V Tauri*	Min.	4659	Jan. 4	57	− 4	3	–	–	–	70	Interpolation by factors
1805	*V Orionis*	Max.	4706.2	Feb. 20	11	+ 2	9	9.07	1.37	1.84	31	One observation only in 1897
2013	*U Aurigae*	Max.	4587	Oct. 24	7	−12	2	8.51	2.0	–	–	Subtangent process
2266	*V Monocerotis*	Min.	4682	Jan. 27	18	+19	4	–	–	–	–	Assumed midway
2478	*R Lyncis*	Min.	4701	Feb. 15	24	−58	3	12.85	2.8	2.8	175	Confirms corrections of last year
2528	*R Geminorum*	Min.	4690	Feb. 4	31	−35	1	12.1	–	–	–	Very uncertain
2625	*V Geminorum*	Max.	4661	Jan. 6	25	+ 7	5	8.57	0.79	0.98	7	
2684	*S Can. min.*	Min.	4740	Mar. 26	40	+54	9	11.42	1.43	1.10	28	
2689	*Z Puppis*	Min.	4730	Mar. 16	–	–	1	10.54	–	–	–	Periodicity not yet established
2690	*X Puppis*	Max.	4640	Dec. 16	–	–	1	8.2	–	–	–	Highest observations
2691	*T Can. min.*	Max.	4756	Apr. 11	33	−31	3	11.5	–	–	–	

INDIVIDUAL OBSERVATIONS.

Including Observations by ARTHUR C. PERRY.

103 *T Andromedae.*

(Cont. from 431. Comp. Stars 346)

Julian	Calendar 1898	Mag.
4546.5	Sept. 13	10.2
4553.5	20	9.65_2
4554.5	21	9.65_2
4560.5	27	9.49_2
4564.5	Oct. 1	9.32_2
4572.5	9	8.96_2
4576.5	13	8.57_2
4580.5	17	8.51_2

103 *T Androm.* — Cont.

Julian	Calendar 1898	Mag.
4585.5	Oct. 22	9.01_2
4590.5	27	9.16_2
4595.5	Nov. 1	9.11_2

419 *U Andromedae.*

(Cont. from 431 Comp. Stars 431)

Julian	Calendar 1898	Mag.
4569.5	Oct. 6	9.8
4572.5	9	10.05_2
4576.6	13	9.86_2

419 *U Androm.* — Cont.

Julian	Calendar 1898	Mag.
4580.5	Oct. 17	10.00_2
4606.5	Nov. 12	10.09_2
4625.5	Dec. 1	10.35_2
4651.5	27	10.9

466 *U Piscium.*

(Cont. from 431 Comp. Stars 431)

Julian	Calendar 1898	Mag.
4625.5	Dec. 1	11.38_2
4631.5	7	11.14_2

466 *U Piscium.* — Cont.

Julian	Calendar 1898	Mag.
4638.5	Dec. 14	11.21_2
4651.5	27	11.48

513 *R Piscium.*

(Continued from 438.)

Julian	Calendar 1898	Mag.
4596.6	Nov. 2	10.53
4609.5	15	9.63_2
4614.6	20	8.70_2
4624.5	30	8.64_2

513 *R Piscium.* — Cont.

Julian	Calendar 1898	Mag.
4630.5	Dec. 6	8.92_2
4532.5	8	8.4_P
4638.5	14	8.77_2
4647.5	23	9.10_2
4654.5	30	9.41

782 *R Arietis.*

(Continued from 438.)

Julian	Calendar 1898	Mag.
4596.6	Nov. 2	8.83_2

782 R Arietis. — Cont.

Julian	Calendar	Mag.
	1898	
4600.6	Nov. 6	8.49_2
4609.5	15	8.50_2
4615.5	21	8.40_2
4625.5	Dec. 1	8.87_2
4631.5	7	8.96_2
4632.5	8	8.94_2

(857) — Ceti.
(Cont. from 438. Comp. Stars 377)

Julian	Calendar	Mag.
	1898	
4601.6	Nov. 7	9.94_2
4605.6	11	9.09_2
4608.5	14	9.10_2
4609.5	15	9.56_2
4638.5	Dec. 14	8.93_2
4639.5	15	8.91_2
4640.5	16	8.77_2
4642.5	18	8.81_2
	1899	
4673.5	Jan. 18	8.87_2
4674.5	19	8.89_2
4675.5	20	8.61_2
4676.5	21	8.81_2

906 R Trianguli.
(Continued from 438.)

Julian	Calendar	Mag.
	1898	
4563.6	Sept. 30	6.22_2
4564.6	Oct. 1	6.02_2
4569.6	6	6.46_2
4572.5	9	5.40_2
4575.5	12	6.35_2
4583.5	20	6.54_2
4587.6	24	6.36_2

976 T Arietis.
(Cont. from 403. Comp. Stars 403)

Julian	Calendar	Mag.
	1898	
4630.5	Dec. 6	8.23_2
4631.5	7	8.68_2
4633.5	9	8.22_2
4639.5	15	8.18_2
4642.6	18	8.55_2
4653.5	29	8.12_2

976 T Arietis. — Cont.

Julian	Calendar	Mag.
	1899	
4662.5	Jan. 7	8.32_2
4669.6	14	8.13_2
4677.5	22	8.49_2
4690.5	Feb. 4	8.65_2

1113 U Arietis.
(Cont. from 438. Comp. Stars 314)

Julian	Calendar	Mag.
	1898	
4575.6	Oct. 12	9.6
4596.6	Nov. 2	8.03_2
4609.5	15	7.61_2
4615.5	21	7.44_2
4630.5	Dec. 6	7.88_2
4635.5	11	7.86_2
4642.6	18	7.90_2
4653.5	29	8.34_2
	1899	
4662.5	Jan. 7	8.06_2
4669.6	14	8.21_2

1166 X Ceti.
(Continued from 438.)

Julian	Calendar	Mag.
	1898	
4625.5	Dec. 1	10.11_2
4633.5	9	9.69_2
4639.5	15	10.12_2
4640.5	16	9.78_2
4650.5	26	9.71_2
4653.5	29	10.09_2
	1899	
4656.5	Jan. 1	9.81_2
4663.5	8	9.81_2
4673.5	18	9.57_2
4675.5	20	9.51_2
4677.5	22	9.70_2
4680.5	25	9.69_2
4682.5	27	9.88_2

1577 R Tauri.
(Continued from 438.)

Julian	Calendar	Mag.
	1898	
4579.5	Oct. 16	8.80_2
4587.6	24	9.23_2
4596.6	Nov. 2	9.32_2
4632.5	Dec. 8	7.4P
4653.5	29	11.0
	1899	
4657.5	Jan. 2	10.26

1582 S Tauri.
(Continued from 438.)

Julian	Calendar	Mag.
	1898	
4635.5	Dec. 11	12.3]
4653.5	29	10.4
	1899	
4657.5	Jan. 2	9.78_2
4665.5	10	9.87_2
4673.5	18	9.66_2
4687.5	Feb. 1	9.92_2
4690.5	4	9.76_2
4694.5	8	9.74_2
4713.5	27	9.97
4724.5	Mar. 10	9.94_2

1717 V Tauri.
(Continued from 433.)

Julian	Calendar	Mag.
	1898	
4625.5	Dec. 1	10.14_2
4635.5	11	11.3
	1899	
4690.5	Feb. 4	11.21_2
4695.5	9	10.13_2
4700.5	14	4.93_2
4713.5	27	9.54_2

1805 V Orionis.
(Continued from 403.)

Julian	Calendar	Mag.
	1897	
4200.7	Oct. 2	10.5
	1898	
4640.5	Dec. 16	12.4
	1899	
4662.6	Jan. 7	10.07_2
4690.5	Feb. 4	9.74_2
4694.5	8	9.53_2
4714.5	28	9.03_2
4715.5	Mch. 1	9.21_2
4719.6	5	9.17_2
4724.5	10	9.12_2
4728.5	14	9.46_2

2013 U Aurigae.
(Continued from 438.)

Julian	Calendar	Mag.
	1898	
4590.6	Oct. 27	8.53_2
4598.6	Nov. 4	8.59_2
4600.6	6	9.67_2
4614.6	20	9.16_2
4635.5	Dec. 1	9.63_2

2266 V Monocerotis.
(Cont. from 438. Comp. Stars 403)

Julian	Calendar	Mag.
	1898	
4640.6	Dec. 16	11.2
	1899	
4690.5	Feb. 4	11.7
4715.5	Mar. 1	11.5
4743.5	29	10.58_2
4748.5	Apr. 3	10.25_2
4755.5	10	10.05_2
4760.6	15	10.09_2

2478 R Lyncis.
(Continued from 441.)

Julian	Calendar	Mag.
	1898	
4600.6	Nov. 6	10.70_2
4638.6	Dec. 14	11.8
	1899	
4775.6	Apr. 30	11.5

2528 R Geminorum.
(Continued from 350.)

Julian	Calendar	Mag.
	1897	
3930.6	Jan. 5	11.7
3980.6	Feb. 24	12]
4045.5	Apr. 30	10.9
4286.5	Dec. 27	12]
	1898	
4423.5	May 13	9.4
4638.6	Dec. 14	11.4
	1899	
4775.6	Apr. 30	10.61_3

2625 V Geminorum.
(Continued from 441.)

Julian	Calendar	Mag.
	1898	
4642.6	Dec. 18	9.5
	1899	
4657.6	Jan. 2	8.70_2
4662.5	7	8.48_2
4665.5	10	8.67_2
4669.5	14	8.80_2

2684 S Can. minoris.
(Cont. from 441 Comp. Stars 441)

Julian	Calendar	Mag.
	1898	
4640.5	Dec. 16	9.6
4642.6	18	9.96_2
	1899	
4662.6	Jan. 7	10.57_2
4696.5	Feb. 11	10.78_2

2684 S Can. min. Cont.

Julian	Calendar	Mag.
	1899	
4700.5	Feb. 14	10.71_2
4715.5	Mar. 1	11.31_2
4724.5	10	10.62_2
4728.5	14	11.22_2
4744.6	30	11.78_2
4750.5	Apr. 5	11.56_2
4755.5	10	10.73_2
4760.5	15	10.69_2
4772.5	27	8.92;

2689 Z Puppis.
(Cont. from 441. Comp. Stars 403)

Julian	Calendar	Mag.
	1898	
4638.7	Dec. 14	10.0]
4640.7	16	10.2P
4642.7	18	10.1
	1899	
4662.6	Jan. 7	9.61_2
4669.6	14	10.06_2
4673.6	18	10.04_2
4690.5	Feb. 4	9.8
4700.5	14	10.47_2
4715.6	Mar. 1	10.45_2
4730.5	16	10.54_2
4747.5	Apr. 2	10.45_2
4748.6	3	10.2P
4774.6	29	10]P

2690 X Puppis.
(Cont. from 441. Comp. Stars 403)

Julian	Calendar	Mag.
	1898	
4640.7	Dec. 16	8.2P
	1899	
4662.6	Jan. 7	8.74_2
4748.6	Apr. 3	8.6P
4774.6	29	8.6P

2691 T Can. minoris.
(Continued from 326)

Julian	Calendar	Mag.
	1898	
4642.6	Dec. 18	13]
	1899	
4749.5	Apr. 4	11.6
4750.5	5	11.63_2
4756.5	11	11.51_2
4772.5	27	12.09;
4779.5	May 4	11.8

Comparison-Stars, 1893–1899.

513 R Piscium.

Star	DM.	Mag.	n
G	+2°207	7.29	2
H	+2°227	7.45	2
1 H	+2°204	7.65	1
K	+3°199	7.63	3
L	+2°229	8.14	30
1 L	+3°205	8.98	2
N	+1°269	9.46	1
P	+2°217	9.21	2
Q	+1°271	9.16	26
R	+2°216	9.18	2
S	+2°221	9.09	45
T	+2°224	9.49	46
W	+2°223	10.21	13
1 Z	+2°226	10.40	3
a	15p Q	10.29	10
c	4n3f T	10.89	5
e	1n6p T	10.88	3

782 R Arietis.

Star	DM.	Mag.	n
2 C	+23°297	5.63	1
1 F	+24°325	6.42	8
2 I	+23°293	6.36	1
J	+23°296	7.05	2
N	+23°295	7.64	3
R	+23°304	7.83	5
1 R	+24°322	7.95	11
2 R	+24°318	8.11	3
T	+24°319	8.06	11
1 T	+23°301	8.34	5
U	+23°306	8.20	1
W	+24°324	8.46	6
1 W	+24°316	8.40	3
X	+24°323	8.55	2
Y	+24°334	9.07	5
1 Y	+24°327	9.47	4
Z	+24°331	9.57	5

1166 X Ceti.

Star	DM.	Mag.	n
G	−2°604	7.88	4
L	−2°607	9.25	8
U	−2°605	9.99	3
1 U	−2°606	9.67	1
X	−1°473	9.61	11
1 X	−1°478	10.36	4
2 X	−1°471	9.94	4
Z	−1°474	9.94	10
1 Z	−1°476	10.27	30
2 Z	−1°470	9.95	4
a	2nf 2X	10.19	1
b	12s12f V	10.94	6
1 b	3f c	10.84	2
c	5n9f 1Z	10.90	3
d	7n3f 2X	11.39	6
e	8p 1Z	11.48	4
f	10n Z	11.44	4

2625 V Geminorum.

Star	DM.	Mag.	n
H	+13°1641	7.67	9
I	+13°1637	8.09	8
2 I	+13°1663	7.50	2
M	+13°1655	7.99	6
R	+13°1640	7.90	3
T	+13°1652	8.80	6
U	+13°1639	8.93	4
Y	+13°1654	9.62	27
Z	+13°1649	9.86	13
1 Z	+13°1650	9.34	12
2 Z	+13°1648	9.83	11
3 Z	+13°1659	8.80	1
c	2n2p M	11.01	6
g	6n6p V	11.84	2
k	5n1f V	12.60	3
m	1s V	13.07	2
o	3n7f V	13.53	1

PARABOLIC ELEMENTS OF COMET 1898 VIII,

By ROGER SPRAGUE.

From the observations of Mt. Hamilton, 1898 Nov. 23, and 1899 Jan. 29, and Strassburg, 1899 April 4, I have computed the following elements of Comet 1898 VIII. The Mt. Hamilton observations were kindly furnished to the Students' Observatory by mail. The Strassburg observation was taken from the *Astron. Nachr.* after applying a slight correction to the reductions to apparent place. In order to secure the greatest accuracy in the elements, especially in T and ω, the final values were derived by Professor LEUSCHNER's differential formulas (*Beiträge zur Kometenbahnbestimmung*, pages 28–29.)

1898–99	Local M.T.	App. α	App. δ	Obsns.
	h m s	h m s	° ′ ″	
Nov. 23	17 8 11	10 21 48.07	+23 36 6.5	Lick
Jan. 29	8 29 28	11 9 25.60	+34 0 35.7	Lick
April 4	9 11 34	10 44 11.62	+37 33 7.1	Strass.

University of California, Students' Observatory, 1899 *July* 11.

ELEMENTS.

$$T = \text{Sept. } 20.073795 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} i &= 22^\circ\ 30'\ 27''.3 \\ \Omega &= 95\ 51\ 25.2 \\ \omega &= 4\ 35\ 31.9 \\ \pi &= 100\ 26\ 57.1 \end{aligned}\right\} 1899.0$$

$$\log q = 0.358758$$

$$\text{O}-\text{C} \qquad \Delta\lambda \cos\beta = -1''.5 \qquad \Delta\beta = -1''.7$$

CONSTANTS TO THE EQUATOR OF 1899.0

$$\begin{aligned} x' &= [0.3247374] \sin(190^\circ\ 55'\ 42''.00 + v) \sec^2\tfrac{1}{2}v \\ y' &= [0.3334251] \sin(109\ 15\ 29.25 + v) \sec^2\tfrac{1}{2}v \\ z' &= [0.0621375] \sin(\ 56\ 12\ 13.61 + v) \sec^2\tfrac{1}{2}v \end{aligned}$$

REDUCTION OF ELEMENTS TO 1898.0

$$\Delta\Omega = -49.12 \qquad \Delta\pi = -50.34 \qquad \Delta i = +0.10$$

OBSERVATIONS OF ζ *HERCULIS*,

MADE WITH THE 28-INCH REFRACTOR AT GREENWICH.

(Communicated by the Astronomer Royal.)

With reference to Professor DOOLITTLE's note on the position of ζ *Herculis* in *A.J.* 466, the following observations, including those made this year, may be of interest. The components were clearly separated on all occasions except 1897.320 and 1897.512, when the seeing was bad. Powers of 670 and 1030 were used for the measures.

Date	p	s	Obs.	Nights
	°	″		
1894.541	40.4	1.23	Lewis	3
95.144	37.9	0.67	Lewis	1
96.449	6.6	0.42	Lewis	1
96.455	5.3	0.65	Lewis	1
97.320	7.9	elongated	Lewis	1
1897.381	3.5	0.3 est.	Lewis	1
1897.512	355.5	0.59	Lewis	1
98.419	288.4	0.70	Lewis	1
98.605	286.7	0.43	Lewis	1
98.613	288.4	0.66	Bowyer	1
98.717	289.2	0.46	Bowyer	1
98.739	288.8	0.77	Lewis	1
98.739	285.3	0.40	Bryant	1
99.315	265.1	0.58	Lewis	2
99.353	268.8	0.56	Lewis	1
99.381	266.9	0.56	Lewis	2
99.411	264.4	0.66	Lewis	1
99.468	261.5	0.60	Bowyer	1
1899.486	261.7	0.63	Lewis	2

Royal Observatory, Greenwich, 1899 *August* 3.

NOTICE RESPECTING (79) *EURYNOME.*

Anyone having unpublished observations of *Eurynome*, last opposition in January, 1899, will confer a favor upon the undersigned by publishing them at his earliest convenience, as tables of its motion are preparing.

W. S. EICHELBERGER.

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No. 469.

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OBSERVATIONS OF COMETS 1898 VI AND 1898 IX.

By C. D. PERRINE.

1898 Mt. Hamilton M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			Comet 1898 VI.					
	h m s			m s	′ ″	h m s	° ′ ″		
June 17 14 3 6	143	d10 , 8	+0 27.36	+ 2 22.2	3 47 15.51	+57 56 52.8	n9.887	0.760
19 14 14 13	144	10 , 6	+4 19.74	− 0 42.4	3 59 31.54	+57 25 2.0	n9.888	0.752
20 13 42 50	145	10 , 8	−1 11.88	− 4 9.7	4 5 26.31	+57 7 51.3	n9.845	0.805
22 14 11 0	146	14 , 8	+0 51.34	− 9 18.8	4 17 28.87	+56 28 53.4	n9.867	0.770
23 14 20 54	147	10 , 6	+3 16.44	− 0 53.3	4 23 25.25	+56 7 41.3	n9.870	0.757
24 14 2 2	148	d10 , 8	−0 20.83	− 8 44.9	4 29 10.30	+55 45 47.0	n9.846	0.792
14 51 30	149	10 , 6	−3 9.21	+ 5 9.6	4 29 22.49	+55 44 58.2	n9.892	0.707
25 14 13 16	150	16 , 8	−0 45.50	+ 1 32.1	4 34 59.17	+55 22 12.6	n9.849	0.780
26 14 9 49	151	d16 , 8	−0 45.29	− 2 28.5	4 40 40.44	+54 57 39.1	n9.840	0.787
27 14 7 23	152	d10 , 8	+0 27.48	− 0 11.6	4 46 17.64	+54 32 1.7	n9.831	0.795
28 14 27 43	155	10 , 6	−2 14.89	− 8 44.0	4 51 56.38	+54 4 42.3	n9.847	0.768
July 1 14 26 4	156	18 , 8	−2 27.53	− 6 7.4	5 8 11.70	+52 37 2.1	n9.826	0.781
2 14 45 53	157	d10 , 8	−0 23.57	− 1 35.4	5 13 32.52	+52 4 59.9	n9.839	0.754
8 14 35 51	158	d10 , 8	+0 4.80	− 3 38.6	5 43 34.89	+48 31 20.4	n9.790	0.787
9 15 44 49	159	d 8 , 6	−0 7.55	+ 7 46.3	5 48 34.60	+47 49 40.1	n9.834	0.671
11 15 15 32	160	10 , 6	−2 58.10	− 0 45.8	5 57 46.51	+46 27 19.5	n9.806	0.736
12 14 55 6	161	16 , 8	+0 50.17	− 6 16.8	6 2 15.10	+45 44 38.5	n9.777	0.779
15 24 32	162	14 , 8	+1 8.59	+ 4 25.1	6 2 21.10	+45 43 47.7	n9.806	0.718
13 15 20 51	163	20 , 8	+0 54.94	− 5 10.6	6 6 49.28	+44 59 24.2	n9.797	0.733
14 15 34 12	164	10 , 6	−3 21.60	+ 7 5.2	6 11 16.71	+44 13 21.0	n9.801	0.713
15 15 10 18	165	d10 , 8	+0 26.14	− 6 50.2	6 15 33.48	+43 27 19.0	n9.778	0.762
16 15 21 26	166	10 , 6	+2 9.56	+ 3 0.0	6 19 53.38	+42 38 56.1	n9.782	0.737
17 15 22 52	167	16 , 8	+1 10.28	− 5 1.9	6 21 7.84	+41 49 38.4	n9.776	0.738
18 15 30 58	168	d 8 , 6	−0 6.42	− 5 26.6	6 28 19.92	+40 58 58.5	n9.775	0.730
15 47 5	170	4	. . .	+ 2 12.1	. . . .	+40 58 26.9	. .	0.702
15 59 18	170	10	+1 55.81	. . .	6 28 25.24	. . . .	n9.788	. .
19 15 40 12	171	14 , 8	+0 44.36	+ 7 37.9	6 32 29.56	+40 6 59.7	n9.774	0.719
15 54 56	172	d10 , 8	−0 11.84	+ 2 48.4	6 32 31.89	+40 6 28.3	n9.780	0.696
20 15 29 2	173	d10 , 8	−0 7.77	− 1 58.1	6 36 32.22	+39 14 36.3	n9.762	0.739
21 15 23 5	174	d10 , 8	+0 12.68	− 0 25.2	6 40 33.20	+38 20 48.3	n9.752	0.749
22 15 36 3	175	11 , 8	−0 51.00	− 6 33.6	6 41 34.71	+37 25 2.2	n9.772	0.629
23 15 40 15	176	2	. . .	− 2 36.4	. . . .	+36 28 26.8	. .	0.731
15 55 1	176	6	+5 10.15	. . .	6 48 34.49	. . . .	n9.757	. .
24 15 35 54	177	14 , 8	−1 4.47	− 4 34.8	6 52 25.93	+35 30 54.9	n9.741	0.738
15 52 36	178	d 9 , 6	−0 33.80	− 6 57.0	6 52 28.25	+35 30 13.2	n9.753	0.713
25 15 44 41	179	10 , 6	−1 58.82	+ 4 25.6	6 56 19.70	+34 31 38.8	n9.738	0.730
16 1 13	180	5	. . .	+ 6 52.7	. . . .	+34 30 59.9	. .	0.707
16 5 5	180	d 5	−0 28.51	. . .	6 56 23.00	. . . .	n9.751	. .
26 15 50 16	181	8 , 5	−1 33.28	+ 5 38.3	7 0 11.19	+33 31 16.2	n9.740	0.723
27 15 48 33	182	d10 , 8	−0 15.70	+ 6 34.8	7 3 59.65	+32 29 59.2	n9.735	0.727
28 15 52 27	183	10 , 6	−1 20.57	− 5 30.6	7 7 47.78	+31 27 10.0	n9.732	0.733
29 15 17 0	184	d10 , 8	+0 13.77	−10 0.7	7 11 33.02	+30 23 36.7	n9.726	0.733
16 0 27	185	d 8 , 6	−0 39.01	+ 0 55.0	7 11 35.27	+30 23 0.9	n9.730	0.715
30 15 45 47	187	d10 , 8	+0 13.03	+ 8 46.3	7 15 18.44	+29 18 41.8	n9.720	0.736
16 0 16	188	10 , 6	+0 45.12	+ 1 16.6	7 15 20.55	+29 17 58.9	n9.725	0.719

1898 Mt. Hamilton M.T.	∗	No. Comp.	☄ − ∗ Δα	☄ − ∗ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			Comet 1898 VI. — Cont.					
d h m s			m s	′ ″	h m s	° ′ ″		
Aug. 1 16 12 52	190	d 8 , 6	−0 25.52	− 4 33.1	7 22 50.67	+27 3 39.5	n9.719	0.708
2 16 1 3	191	d 8 , 6	+0 10.31	+ 0 2.5	7 26 32.77	+25 55 37.9	n9.713	0.725
16 11 8	193	10 , 6	−0 33.37	− 1 39.5	7 26 34.30	+25 55 9.1	n9.715	0.713
4 16 2 12	194	10 , 6	−0 40.00	+ 6 7.4	7 34 0.10	+23 34 57.4	n9.704	0.724
16 2 12	195	10	−0 22.11	. . .	7 34 0.06	. . . .	n9.704	. .
16 9 47	195	6	. . .	+ 6 51.2	. . . .	+23 34 34.8	. .	0.719
16 14 35	196	4	. . .	− 1 4.8	. . . .	+23 34 21.7	. .	0.709
16 20 2	196	d 8	+0 28.77	. . .	7 34 2.79	. . . .	n9.707	. .
5 16 6 54	198	10 , 6	+1 3.94	− 5 5.1	7 37 44.90	+22 22 44.6	n9.702	0.723
16 16 21	199	4	. . .	+ 2 10.8	. . . .	+22 22 12.4	. .	0.712
16 20 48	199	d 8	−0 16.72	. . .	7 37 47.06	. . . .	n9.704	. .
6 16 2 31	201	20 , 10	−0 19.27	− 1 16.6	7 41 29.08	+21 9 52.9	n9.696	0.730
7 16 3 42	202	20 , 8	+0 31.96	− 3 42.8	7 45 15.07	+19 55 46.0	n9.694	0.729
8 16 3 51	203	10 , 6	+0 44.36	− 7 28.4	7 49 1.99	+18 40 40.9	n9.691	0.732
10 16 14 50	204	d 6 , 8	−0 10.13	− 4 42.7	7 56 41.40	+16 7 10.0	n9.687	0.726
16 23 43	204	5	. . .	− 5 11.2	. . . .	+16 6 41.5	. .	0.719
			Comet 1898 IX.					
d h m s			m s	′ ″	h m s	° ′ ″		
Sept. 16 16 9 44	205	10 , 8	−1 0.00	− 3 41.0	10 0 11.73	+28 55 31.4	n9.730	0.676
17 16 28 9	206	10 , 8	+0 41.39	− 2 17.3	10 6 31.43	+28 18 14.8	n9.727	0.655
18 16 9 1	207	10 , 9	−0 21.59	− 3 9.2	10 12 43.56	+27 40 6.1	n9.724	0.688
19 16 21 8	208	10 , 8	+1 20.17	− 1 1.1	10 19 6.12	+26 59 18.5	n9.722	0.677
16 40 42	209	10 , 6	+0 44.64	+ 7 0.1	10 19 11.54	+26 58 46.1	n9.720	0.652
20 16 9 44	210	10 , 8	+1 55.63	− 7 36.2	10 25 24.10	+26 17 19.7	n9.719	0.695
22 16 2 54	211	10 , 8	−1 23.92	− 1 47.4	10 38 9.22	+24 47 17.1	n9.711	0.714
16 36 55	212	10 , 6	+2 43.75	+ 2 58.3	10 38 18.37	+24 46 11.0	n9.713	0.677
26 16 43 6	213	d10 , 8	+0 5.93	−11 30.5	11 4 7.22	+21 22 10.8	n9.702	0.692
27 16 43 9	214	10 , 6	−1 29.99	− 5 54.0	11 10 35.86	+20 26 27.2	n9.700	0.697
28 16 44 48	215	10 , 8	−1 0.00	− 6 42.7	11 17 5.25	+19 28 39.2	n9.697	0.701
29 16 49 20	216	10 , 8	+1 12.98	+ 0 48.0	11 23 35.69	+18 29 3.5	n9.695	0.702
Oct. 3 16 47 8	217	10 , 8	−0 41.75	+ 1 36.2	11 49 33.32	+14 12 24.6	n9.685	0.720
17 2 38	217	10 , 8	−0 37.34	+ 0 52.6	11 49 37.73	+14 11 41.0	n9.685	0.710
4 17 3 59	218	d10 , 8	+0 4.68	+ 6 34.5	11 56 7.32	+13 3 1.3	n9.683	0.713
5 17 2 18	219	10 , 8	−1 30.83	+ 1 28.7	12 2 36.27	+11 52 52.1	n9.681	0.719
9 17 11 40	220	10 , 6	−0 36.58	− 1 4.4	12 28 35.23	+ 6 55 34.0	n9.675	0.724

Mean Places for 1898.0 of Comparison-Stars.

∗	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
143	3 46 46.74	+1.44	+57 54 29.0	+1.6	Helsingfors–Gotha A.G. 3264
144	3 55 10.27	+1.53	+57 25 42.9	+1.5	" " 3336
145	4 6 39.62	+1.57	+57 11 59.4	+1.6	" " 3434
146	4 16 35.90	+1.63	+56 38 10.7	+1.5	" " 3527
147	4 20 7.15	+1.66	+56 8 33.1	+1.5	" " 3552
148	4 29 29.45	+1.68	+55 54 30.5	+1.4	" " 3649
149	4 32 30.02	+1.68	+55 39 47.1	+1.5	" " 3677
150	4 35 42.97	+1.70	+55 20 39.1	+1.4	" " 3708
151	4 41 24.01	+1.72	+55 0 6.3	+1.3	" " 3762
152	4 45 48.42	+1.74	+54 32 12.1	+1.2	Micrometer comparison with ∗153 and 154
153	4 39 52.58	+1.75	+54 37 52.9	+1.2	Rogers, Cambridge A.G. Catal. 1953
154	4 40 15.75	+1.75	+54 38 28.0	+1.2	" " " " 1957
155	4 54 9.50	+1.77	+54 13 25.3	+1.0	" " " " 2037
156	5 10 37.37	+1.86	+52 43 8.8	+0.7	" " " " 2140
157	5 13 54.20	+1.89	+52 6 34.7	+0.6	" " " " 2153
158	5 43 28.08	+2.01	+48 34 58.8	+0.2	Deichmüller, Bonn A.G. Catal. 4766

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
159	5 48 40.14	+2.01	+47 41 53.8	0.0	Deichmüller, Bonn A.G. Catal. 4830
160	6 0 42.59	+2.02	+46 28 5.5	− 0.2	" " " 5007
161	6 1 23.19	+2.04	+45 50 55.7	− 0.4	" " " 5016
162	6 1 10.67	+2.04	+45 39 22.9	− 0.3	" " " 5013
163	6 5 52.29	+2.05	+45 4 35.3	− 0.5	" " " 5084
164	6 14 36.26	+2.05	+44 6 16.5	− 0.7	" " " 5184
165	6 15 5.26	+2.08	+43 34 10.0	− 0.8	" " " 5191
166	6 17 41.74	+2.08	+42 35 56.9	− 0.8	" " " 5225
167	6 22 55.46	+2.10	+41 54 41.2	− 0.9	" " " 5278
168	6 28 24.23	+2.11	+41 4 26.1	− 1.0	Micrometer-Comparison with *169
169	6 27 20.34	+2.11	+41 8 13.9	− 1.0	Deichmüller, Bonn A.G. Catal. 5342
170	6 26 27.32	+2.11	+40 56 15.8	− 1.0	" " " 5335
171	6 31 43.09	+2.11	+39 59 22.8	− 1.0	" " " 5391
172	6 32 41.62	+2.11	+40 3 41.0	− 1.1	" " " 5405
173	6 36 37.88	+2.11	+39 16 35.5	− 1.1	Lund A.G. Zones 370, 500
174	6 40 18.41	+2.11	+38 21 14.7	− 1.2	" " 501, 506
175	6 45 26.60	+2.11	+37 31 37.1	− 1.3	" " 500, 638
176	6 43 22.23	+2.11	+36 31 4.6	− 1.4	" " 153, 157
177	6 53 28.30	+2.10	+35 35 31.2	− 1.5	" " " "
178	6 52 59.95	+2.10	+35 37 11.7	− 1.5	" " 112, 131
179	6 58 16.43	+2.09	+34 27 14.8	− 1.6	Leyden A.G. Zones 164, 279
180	6 56 49.42	+2.09	+34 24 8.8	− 1.6	" " 14, 279
181	7 1 42.38	+2.09	+33 25 39.6	− 1.7	" " 161, 401
182	7 4 13.26	+2.09	+32 23 26.2	− 1.8	½(Paris 8745+Brussells 2967)
183	7 9 6.25	+2.10	+31 32 42.6	− 2.0	Leyden A.G. Zones 147, 254
184	7 11 17.14	+2.11	+30 33 39.4	− 2.0	" " 272, 350
185	7 12 12.18	+2.10	+30 22 7.9	− 2.0	Micrometer-comparison with *186
186	7 14 6.61	+2.10	+30 26 17.5	− 2.1	Leyden A.G. Zones 272, 350
187	7 15 3.30	+2.11	+29 9 57.5	− 2.0	Graham, Cambridge A.G. Catal. 3913
188	7 14 33.32	+2.11	+29 16 44.4	− 2.1	Micrometer-comparison with *189
189	7 12 25.97	+2.12	+29 17 7.1	− 2.0	Graham, Cambridge A.G. Catal. 3887
190	7 23 14.08	+2.11	+27 8 14.8	− 2.2	" " " 3986
191	7 26 20.36	+2.10	+25 55 37.6	− 2.2	Micrometer-comparison with *192
192	7 24 38.37	+2.11	+25 56 48.9	− 2.1	Graham, Cambridge A.G. Catal. 4002
193	7 27 5.57	+2.10	+25 56 50.8	− 2.2	" " " 4035
194	7 34 38.02	+2.08	+23 28 52.3	− 2.3	Becker, Berlin A.G. Catal. 3060
195	7 34 20.09	+2.08	+23 27 45.9	− 2.3	" " " 3059
196	7 33 31.94	+2.08	+23 35 28.8	− 2.3	Micrometer-comparison with *197
197	7 35 37.08	+2.08	+23 45 6.5	− 2.4	Becker, Berlin A.G. Catal. 3072
198	7 36 38.89	+2.07	+22 27 52.0	− 2.3	" " " 3079
199	7 38 1.70	+2.08	+22 20 3.8	− 2.2	Micrometer-comparison with *200
200	7 35 30.60	+2.07	+22 21 16.9	− 2.2	Becker, Berlin A.G. Catal. 3071
201	7 41 46.30	+2.05	+21 11 11.9	− 2.4	" " " 3120 [lin A.G.3054)
202	7 44 41.07	+2.04	+19 59 31.3	− 2.5	½(" " " 3142+Auwers, Ber-
203	7 48 15.60	+2.03	+18 48 11.8	− 2.5	Auwers, Berlin A.G. Catal. 3087
204	7 56 49.52	+2.01	+16 11 55.5	− 2.8	" " " 3172
205	10 1 9.36	+2.37	+28 59 25.6	−13.2	Graham, Cambr. A.G. Catal. 5213
206	10 5 47.69	+2.35	+28 20 45.5	−13.4	" " " 5241
207	10 13 2.83	+2.32	+27 43 28.9	−13.6	" " " 5294
208	10 17 43.65	+2.30	+27 0 33.4	−13.8	" " " 5330
209	10 18 24.59	+2.31	+26 51 59.7	−13.7	" " " 5338
210	10 23 26.17	+2.30	+26 25 9.9	−14.0	" " " 5370 [lin 4089)
211	10 39 30.87	+2.27	+24 49 18.8	−14.3	½(" " " 5484+Becker, Ber-
212	10 35 32.31	+2.28	+24 43 27.0	−14.3	Becker, Berlin A.G. Catal. 4077
213	11 3 59.07	+2.22	+21 33 56.1	−14.8	" " " 4201
214	11 12 3.65	+2.20	+20 32 36.0	−14.8	" " " 4230
215	11 18 3.07	+2.18	+19 35 36.7	−14.8	Auwers, Berlin A.G. Catal. 4419
216	11 22 20.54	+2.17	+18 28 30.3	−14.8	" " " 4432
217	11 50 12.95	+2.12	+14 11 3.3	−14.9	W. Bessel 822
218	11 56 0.52	+2.12	+12 56 41.7	−14.9	Grant, Glasgow 3080
219	12 4 4.99	+2.11	+11 51 38.3	−14.9	W. Bessel 4
220	12 29 9.69	+2.12	+ 6 56 53.2	−14.8	M_1 8230

COMET 1898 VI.

June 15th, Comet 1½′ in diameter; 10½^M. Central condensation but no nucleus. — 19th, No well-defined nucleus, otherwise nearly as bright as Comet *b*. — 20th, Comet *e* same brightness as Comet *b*. Comet *e* has a nucleus which is fairly sharp. — 23d, Comet is brighter. Nucleus of 13^M. — 24th, Comet *e* is almost twice as bright as Comet *b*. Comet *e* is about 9½^M. — 25th, 36-inch refractor. Comet brightens gradually to a central condensation, but there is no nucleus proper. — 28th, Nucleus much sharper than heretofore = 10½^M or 11^M. — *July* 8th, Comet easy, fully as bright as 9^M.0. Nucleus seems sharp. — 11th, Comet bright and has a nucleus of 11^M-12^M. — 12th, Wind shakes telescope some. Comet bright and easy = 8½^M. Nucleus 10½^M or 11^M. — 14th, Nucleus 11^M-12^M. — 15th, Nucleus quite bright = 10^M or 10½^M. Comet 8½^M or 9^M. — 16th, Comet 8½^M. — 17th, Comet 8½^M; has a sharp nucleus of 10^M. Seeing good. Short tail in position-angle 305°±. — 19th, Comet 8^M. Can see to bisect it with *dark* wires. Comet still visible at 16^h 12^m P.St. — 20th, Comet has a sharp nucleus of 11^M. — 21st, Sharp nucleus distinctly visible. Comet is brighter than the comparison star of 8^M.5; 8 or 8¼^M. — 22d, Nucleus of 10½^M or 11^M. Comet 8½^M. — 24th, Comet 8^M. Nucleus 10^M-10½^M. Short, bushy tail n.p. — 25th, Comet 8^M or 8½^M. Nucleus of 9½^M or 10^M. Seeing good. — 26th, Observation interrupted by clouds.—27th, Comet is fully 8^M.0, if anything it is brighter. — 28th, Comet brighter than 8^M.0, probably 7^M.5. Has a nucleus of 9½^M. — 29th, Comet 7½^M. Nucleus 9½^M. Tail 3′ or 4′ long n.p. Nucleus same brightness as comparison-star (9^M.5).—30th, Comet fully 3 times as bright as the 8^M.3 comparison-star. — *August* 4th, Comet more easily seen at last measures than 9^M.3 star. Nucleus 9^M.0 — 7th, Nucleus sharp and nearly as bright as 9^M.1 comparison-star. Seeing good. — 10th, All measures made with dark wires. Clouds interfered. — 16th, The comet was looked for but its place was too low in the dawn.

The observations of June 25, July 2, 18, were made with the 36-inch refractor, all the rest were made with the 12-inch telescope.

COMET 1898 IX.

September 12th, Comet 8^M-9^M. Short tail n.f. — 13th, Head of comet about 5′ in diameter. Head is round and has a sharp central condensation, but not stellar. Tail in position-angle 306°.8. — 18th, Position-angle of tail 309°.5. Comet has a condensation 6″ to 8″ in diameter which is fully as bright as the 8^M.9 comparison-star. Comet 7½^M or 8^M. — 19th, Comet much brighter, 7^M. Nucleus much sharper and more condensed, almost stellar, 9½^M or 10^M. — 20th, Comet has stellar nucleus of 10^M. Comet fully 7^M. — 22d, Comet distinctly visible to naked eye. Comet has nucleus which in best seeing is sharp and of 9^M.0. — 26th, Comet very bright. Can see it with naked eye. Nucleus fully as bright as 8^M.8 comparison-star. Tail brighter than on September 22. — 28th, Seeing bad. High, cold north wind which shakes telescope. — *October* 3d, Nucleus not as sharp as a star, but fully 8^M.0. — 5th, Comet low in dawn. No nucleus visible and only a faint tail. — 9th, All measures made through clouds. Comet so near the horizon that all star-images are poor. The effects of irregular refraction are marked. — 10th, Looked for Comet *h* but could not see it in the dawn. Some haze. — 11th, Comet looked for but not found.

All the observations of Comet *h* were made with the 12-inch equatorial.

Lick Observatory, University of California, 1898 *December* 20.

ERRORS IN WEISSE'S CATALOGUE OF BESSEL STARS.

W.B.$_2$ 22^h 259. There appears to be an error of about 10″ in δ in the reduction of this star from the time of observation to the epoch of the catalogue. The declination should be increased about 10″.

W.B.$_2$ 22^h 688. The declination of this star is in error by 1′ 45″. Both the catalogue place and the zone observation should be decreased.

W.B.$_2$ 22^h 395. The right-ascension of this star appears to be 0^s.6 too large.

THE VELOCITY OF METEORS FROM PHOTOGRAPHS,

BY W. L. ELKIN.

We have been experimenting with an apparatus for determining the velocity of meteors photographically, on a principle similar to that devised by LANE as long ago as 1860, and to that used by ZENKER in 1885 but without success apparently (see *Amer. Journal of Science*, Vol. XXX, p. 42, and *Astr. Nachr.*, Vol. CXIII, p. 228). The same plan has been recently suggested by FITZGERALD (*Astrophysical Journal*, Vol. IX, p. 50) and consists in rotating in front of the lens at a known rate a wheel carrying at intervals interceptors of the light falling on the lens. Our apparatus was placed on our meteorograph and was large enough to occult all of the six large lenses now in use. Our second station is now provided with six cameras and both instruments were brought into use during the favorable absence of the moon in the first half of August. Unfortunately the nights of Aug. 10, 11 and 12 were completely overcast here, Aug. 9 partly so, so that no records of *Perseid* meteors seem to show on our plates. But on July 31, Aug. 7 and Aug. 8 each, a meteor trail from other radiants was secured at both stations, those of July 31 and Aug. 8 showing three or four interruptions and of Aug. 7 some ten or twelve on the Yale plates. It is of course a question as to whether the cosmical velocity can be deduced from these records, and it will be of considerable interest to see whether the results thus derived will agree with the known velocity of the *Leonids*, if we are fortunate enough to capture any trails next November.

Yale University Observatory, 1899 *Aug.* 17.

OBSERVATIONS OF *EROS*,

MADE AT THE CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, COLORADO,

By HERBERT A. HOWE.

In *A.J.* 463 are to be found the first observations of the series which is here concluded. The total number of observations is 302. Despite the brightness and duration of the twilight the planet might have been followed further. The computation of the reductions to apparent place was made by Prof. CHAS. J. LING.

1899 Univ. Park M.T.	*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's Apparent α	Planet's Apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
Apr. 7 7 45 7	1	20 , 8	+0 17.87	+ 4 19.8	3 50 6.16	+23 36 22.8	9.678	0.645
7 7 56 9	2	20 , 6	+1 6.08	− 3 17.7	3 50 8.10	+23 36 22.3	9.683	0.657
7 8 3 52	3	20 , 6	−2 26.30	− 1 9.3	3 50 9.48	+23 36 25.6	9.686	0.666
10 7 50 16	4	20 , 6	+3 27.70	+ 0 41.2	4 1 47.91	+23 50 26.3	9.682	0.649
10 7 58 6	5	20 , 6	−1 52.57	+ 1 57.3	4 1 49.10	+23 50 26.0	9.685	0.658
10 8 8 13	6	20 , 6	−2 24.21	+ 7 27.0	4 1 50.80	+23 50 28.1	9.688	0.669
13 7 58 0	7	20 , 6	−3 49.23	− 8 49.8	4 13 35.84	+24 1 26.9	9.686	0.657
13 8 11 59	8	20 , 6	−4 15.35	− 2 43.8	4 13 38.02	+24 1 26.8	9.690	0.672
13 8 25 49	9	20 , 6	−4 15.06	− 2 31.7	4 13 40.35	+24 1 29.2	9.693	0.688
15 7 51 37	10	20 , 8	−0 15.86	− 5 56.4	4 21 28.77	+24 6 59.8	9.683	0.649
15 8 2 51	11	20 , 8	−0 45.01	+13 25.8	4 21 30.80	+24 7 2.6	9.688	0.662
15 8 14 44	12	20 , 8	−0 49.55	+11 30.8	4 21 32.73	+24 7 3.1	9.691	0.675
20 8 6 12	13	20 , 6	−1 20.02	− 1 33.2	4 41 25.60	+24 14 41.1	9.689	0.665
20 8 17 17	14	19 , 6	+2 15.87	+ 1 18.2	4 41 27.48	+24 14 45.3	9.692	0.677
20 8 27 1	15	20 , 6	−3 38.80	+ 7 35.6	4 41 29.15	+24 14 44.1	9.694	0.688
21 7 56 25	16	20 , 6	−1 51.02	+14 31.1	4 45 24.08	+24 15 8.4	9.685	0.654
21 8 7 21	17	20 , 6	−4 41.87	−10 45.7	4 45 25.80	+24 15 9.2	9.689	0.666
22 8 1 30	18	20 , 6	−3 19.51	− 5 17.2	4 49 25.11	+24 15 11.4	9.687	0.659
22 8 9 57	19	10 , 3	−6 49.44	− 5 30.3	4 49 26.57	+24 15 9.6	9.690	0.669
22 8 31 16	20	9 , 3	−7 6.90	+ 4 56.2	4 49 30.39	+24 15 14.0	9.695	0.692
26 8 21 31	21	20 , 8	−0 30.53	+ 2 17.0	5 5 32.76	+24 11 40.8	9.693	0.682
26 8 36 41	22	20 , 6	+3 36.79	+ 3 42.9	5 5 35.29	+24 11 40.0	9.695	0.698
26 8 48 34	23	20 , 7	+0 53.33	− 5 1.8	5 5 37.17	+24 11 38.3	9.695	0.710
27 8 27 1	24	20 , 6	+5 12.13	+ 7 38.0	5 9 35.05	+24 9 49.0	9.694	0.688
27 8 41 4	25	20 , 6	+4 27.22	− 7 21.6	5 9 37.85	+24 9 47.5	9.695	0.704
27 8 56 12	26	20 , 6	+2 45.34	− 6 49.6	5 9 40.09	+24 9 45.7	9.695	0.718
May 3 8 23 37	27	18 , 6	+4 27.45	− 7 34.4	5 33 45.70	+23 50 48.9	9.692	0.685
3 8 33 56	28	20 , 6	−3 12.50	+ 9 31.7	5 33 47.27	+23 50 46.3	9.694	0.696
3 8 47 53	29	20 , 6	−3 26.99	−11 34.0	5 33 49.78	+23 50 44.1	9.694	0.710
4 8 36 38	30	20 , 6	−1 49.62	+ 3 47.7	5 37 49.72	+23 46 15.9	9.694	0.699
4 8 49 24	31	20 , 6	−1 58.48	+ 3 48.0	5 37 51.87	+23 46 11.6	9.694	0.712
4 9 8 46	32	19 , 6	+4 8.63	+ 7 44.1	5 37 55.09	+23 46 8.5	9.692	0.731
5 8 35 55	33	20 , 8	−0 39.13	− 3 41.4	5 41 51.04	+23 41 20.2	9.693	0.698
5 8 47 37	34	20 , 6	−1 41.94	+ 0 37.8	5 41 53.00	+23 41 16.7	9.694	0.710
5 9 0 53	35	20 , 8	+0 17.91	+ 4 15.8	5 41 55.43	+23 41 16.3	9.693	0.723
10 8 23 36	36	20 , 6	+1 37.34	− 0 8.4	6 1 55.18	+23 11 16.8	9.690	0.687
10 8 31 30	37	20 , 6	−1 40.89	+ 3 24.4	6 1 56.46	+23 11 12.2	9.691	0.695
10 8 42 19	38	19 , 6	−2 16.25	+ 5 19.0	6 1 58.24	+23 11 9.5	9.692	0.706
10 8 58 35	39	20 , 8	+0 16.83	− 5 6.1	6 2 1.02	+23 11 5.6	9.692	0.722
11 8 20 56	37	19 , 6	+2 17.71	− 3 40.4	6 5 55.05	+23 4 7.4	9.689	0.685
11 8 32 8	40	19 , 6	+1 33.36	+ 2 54.2	6 5 57.02	+23 4 3.8	9.691	0.696
11 8 44 23	41	30 , 6	−1 22.90	+ 4 33.4	6 5 59.10	+23 3 59.6	9.692	0.708
11 8 59 10	42	15 , 6	−0 40.33	+ 0 8.0	6 6 1.55	+23 3 58.6	9.691	0.723
16 8 35 11	43	20 , 6	−1 59.04	− 2 9.2	6 25 54.51	+22 22 49.5	9.689	0.702
16 8 46 31	44	20 , 6	−2 3.97	+11 8.2	6 25 56.32	+22 22 47.6	9.689	0.712
16 8 56 39	45	20 , 5	−2 5.79	+10 35.8	6 25 57.95	+22 22 39.1	9.689	0.722
17 8 35 1	46	20 , 6	−1 3.42	+ 5 28.6	6 29 52.56	+22 13 29.7	9.688	0.702
17 8 45 12	47	20 , 6	−1 31.67	− 0 32.3	6 29 54.26	+22 13 27.4	9.689	0.712
18 8 30 14	48	20 , 7	+0 46.95	− 3 16.6	6 33 49.11	+22 3 53.0	9.687	0.698
18 8 40 31	49	20 , 7	+0 23.35	− 1 42.9	6 33 50.91	+22 3 47.1	9.688	0.708
18 8 51 49	50	20 , 6	+1 34.38	+ 7 18.5	6 33 52.89	+22 3 43.9	9.688	0.718

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	3 49 17.26	+1.03	+23 31 58.0	+5.0	Becker, Berlin A.G. Catal. 1249
2	3 49 0.99	+1.03	+23 39 35.0	+5.0	" " " " 1245
3	3 52 34.73	+1.05	+23 37 29.9	+5.0	" " " " 1273
4	3 58 19.18	+1.03	+23 49 10.4	+4.7	" " " " 1309
5	4 3 10.61	+1.06	+23 48 21.1	+4.6	" " " " 1341
6	4 4 13.95	+1.06	+23 42 56.6	+4.5	" " " " 1342
7	4 17 23.97	+1.10	+24 10 12.6	+4.1	" " " " 1406
8	4 17 52.27	+1.10	+24 4 6.5	+4.1	" " " " 1416
9	4 17 54.31	+1.10	+24 3 56.8	+4.1	" " " " 1417
10	4 21 43.52	+1.11	+24 12 52.2	+4.0	" " " " 1436
11	4 22 14.70	+1.11	+23 53 32.9	+3.9	" " " " 1439
12	4 22 21.17	+1.11	+23 55 28.4	+3.9	" " " " 1440
13	4 42 41.46	+1.16	+24 16 10.9	+3.4	" " " " 1530
14	4 39 10.46	+1.15	+24 13 23.6	+3.5	" " " " 1512
15	4 45 6.78	+1.17	+24 7 5.2	+3.3	" " " " 1537
16	4 47 13.93	+1.17	+24 0 34.1	+3.2	" " " " 1547
17	4 50 6.48	+1.19	+24 25 51.7	+3.2	" " " " 1574
18	4 52 43.47	+1.18	+24 20 25.5	+3.1	" " " " 1583
19	4 56 14.81	+1.20	+24 20 36.9	+3.0	" " " " 1606
20	4 56 36.09	+1.20	+24 10 14.8	+3.0	" " " " 1611
21	5 6 2.09	+1.20	+24 9 21.4	+2.4	" " " " 1674
22	5 1 57.32	+1.18	+24 7 54.6	+2.5	" " " " 1645
23	5 4 42.65	+1.19	+24 16 37.6	+2.5	" " " " 1664
24	5 4 21.73	+1.19	+24 2 8.6	+2.4	" " " " 1660
25	5 5 9.44	+1.19	+24 17 6.7	+2.4	" " " " 1669
26	5 6 53.55	+1.20	+24 16 32.9	+2.4	" " " " 1676
27	5 29 16.95	+1.30	+23 58 21.7	+1.6	" " " " 1801
28	5 36 58.47	+1.30	+23 41 13.3	+1.3	" " " " 1895
29	5 37 15.46	+1.31	+24 2 16.7	+1.4	" " " " 1898
30	5 39 38.04	+1.30	+23 42 27.0	+1.2	" " " " 1929
31	5 39 49.05	+1.30	+23 42 22.4	+1.2	" " " " 1934
32	5 33 45.18	+1.28	+23 38 23.0	+1.4	" " " " 1854
33	5 42 28.87	+1.30	+23 45 0.5	+1.1	" " " " 1975
34	5 43 33.63	+1.31	+23 40 37.9	+1.0	" " " " 1991
35	5 41 36.22	+1.30	+23 36 59.4	+1.1	" " " " 1958
36	6 0 16.52	+1.32	+23 11 25.1	+0.1	" " " " 2168
37	6 3 36.01	+1.34 / +1.33	+23 7 47.8	0.0 / 0.0	" " " " 2216
38	6 4 13.15	+1.34	+23 5 50.5	0.0	" " " " 2221
39	6 1 42.86	+1.33	+23 16 11.6	+0.1	" " " " 2189
40	6 4 22.32	+1.34	+23 0 57.7	−0.1	" " " " 2222
41	6 7 20.65	+1.35	+22 59 26.4	−0.2	" " " " 2249
42	6 6 40.53	+1.35	+23 3 50.8	−0.2	" " " " 2245
43	6 27 52.14	+1.41	+22 24 59.8	−1.1	" " " " 2452
44	6 27 58.88	+1.41	+22 11 40.5	−1.1	" " " " 2454
45	6 28 2.33	+1.41	+22 12 4.4	−1.1	" " " " 2455
46	6 30 54.57	+1.41	+22 8 2.3	−1.2	" " " " 2477
47	6 31 24.52	+1.41	+22 14 0.9	−1.2	" " " " 2480
48	6 33 0.75	+1.41	+22 7 10.8	−1.2	" " " " 2499
49	6 33 26.15	+1.41	+22 5 31.6	−1.3	" " " " 2507
50	6 32 17.11	+1.40	+21 56 26.7	−1.3	" " " " 2495

NEW ASTEROID.

Communicated by Prof. KREUTZ.

	1899		α	δ	Discoverer
		h m	h m s	° ′ ″	
EP 11ᴹ.0	Aug. 26	10 33.1 Paris M.T.	21 29 18.5	−6 4 45	Jean Mascart
	26	14 24.1 " "	21 29 10.8	−6 5 35	

OBSERVATIONS OF THE INNER SATELLITES OF *SATURN*,

MADE WITH THE 26-INCH REFRACTOR AT THE LEANDER McCORMICK OBSERVATORY AT THE UNIVERSITY OF VIRGINIA,

By J. ADAIR LYON.

Dione–Rhea.

1899	Eastern M.T. (h m s)	p (°)	Eastern M.T. (h m s)	s (″)
April 16	15 9 1	100.44	15 15 41	33.58
	15 25 33	100.61	15 19 55	33.85
26	14 34 28	63.97	14 39 50	92.79
	14 45 46	65.02	14 43 46	92.89
30	13 23 3	115.91	13 28 59	29.53
	13 36 5	116.35	13 32 53	29.85
	14 27 5	116.84	14 31 29	30.67
	14 40 23	117.16	14 34 41	31.20
	15 21 42	118.40	15 25 23	31.30
	15 31 33	119.14	15 28 10	31.90
	16 11 48	119.62	16 15 46	32.21
	16 21 45	119.85	16 18 25	31.81
May 25	13 8 23	56.56	13 12 53	73.99
	13 19 9	57.19	13 15 27	74.56
	14 55 14	63.77	15 2 56	80.28
	15 9 55	64.99	15 5 56	80.25
28	12 34 28	218.91	12 40 37	24.39
	12 46 29	220.69	12 43 3	24.67
June 2	12 29 48	306.13	12 33 46	54.58
	12 39 44	306.63	12 36 37	54.18
	13 26 20	309.50	13 29 15	50.66
	13 37 24	310.06	13 31 50	51.19
	15 5 4	316.00	15 11 44	38.83
	15 17 14	317.20	15 14 13	38.51
3	12 16 53	57.64	12 20 40	17.06
	12 25 32	55.86	12 23 0	17.23
	13 49 28	55.96	13 52 24	15.61
	13 57 13	56.35	13 54 16	15.83
4	14 46 1	68.91	14 50 8	40.07
	14 56 2	69.44	14 52 58	40.21
8	12 58 20	84.63	13 2 21	109.29
	13 9 6	84.82	13 5 34	108.93
18	14 22 18	89.90	14 24 48	59.22
	14 31 12	89.86	14 27 27	58.65
21	13 33 24	22.40	13 38 43	63.30
	13 44 40	23.67	13 41 53	63.44
24	9 55 56	267.54	9 58 58	25.16
	10 4 16	267.69	10 2 8	25.20
	10 31 38	267.37	10 35 22	23.87
	10 39 26	267.43	10 37 12	23.99
	11 13 38	266.74	11 16 12	23.20
	11 22 29	266.71	11 18 32	23.55

Tethys–Dione.

1899	Eastern M.T. (h m s)	p (°)	Eastern M.T. (h m s)	s (″)
April 16	15 32 19	119.73	15 48 27	10.67
	15 56 31	119.68	15 51 47	10.27
26	14 12 3	81.03	14 18 52	77.70
	14 28 21	81.99	14 23 5	77.48
	16 5 23	87.35	16 11 36	82.21
	16 20 18	88.21	16 15 57	82.68
30	13 41 25	160.00	13 48 13	40.51
	13 57 5	163.92	13 51 9	41.03
	14 47 1	174.68	14 52 40	39.34
	14 57 56	177.72	14 55 13	38.75
	15 36 54	187.27	15 42 6	38.91
	15 50 19	189.07	15 45 9	39.39

Tethys–Dione. — Cont.

1899	Eastern M.T. (h m s)	p (°)	Eastern M.T. (h m s)	s (″)
May 25	13 51 29	258.96	13 55 26	86.53
	14 1 6	259.67	13 58 8	85.68
	15 44 8	265.94	15 48 28	94.05
	15 54 54	266.54	15 51 58	94.45
28	12 53 1	311.22	12 56 27	20.06
	13 0 19	311.69	12 58 20	19.56
June 2	12 58 56	267.95	13 2 30	75.05
	13 7 36	268.58	13 4 41	74.45
	14 12 36	271.58	14 16 47	74.70
	15 22 44	271.78	14 19 24	73.70
	15 23 20	275.28	15 27 40	74.11
	15 33 38	275.88	15 30 28	73.74
3	11 51 42	62.99	11 54 40	24.64
	12 0 22	63.39	11 57 30	25.00
	13 19 5	69.64	13 21 48	25.76
	13 28 12	70.34	13 25 6	25.90
4	13 49 57	87.91	13 54 24	23.87
	13 59 38	87.78	13 56 46	24.01
	15 2 2	87.70	15 7 59	26.19
	15 13 50	90.67	15 10 26	26.19
8	13 11 52	124.21	13 23 8	56.65
	13 30 2	126.80	13 27 8	56.06
18	14 36 52	135.15	14 40 28	59.77
	14 45 25	135.92	14 43 2	59.13
21	12 43 11	264.40	12 46 42	44.07
	12 53 6	265.13	12 49 30	43.88
	13 49 17	267.77	13 53 20	44.76
	14 0 10	268.50	13 56 46	44.46
24	9 30 48	197.23	9 34 2	40.73
	9 39 20	199.70	9 36 58	40.59
	10 9 14	207.15	10 13 0	42.04
	10 18 1	208.21	10 15 8	42.54
	10 44 42	213.15	10 47 8	44.43
	10 51 12	214.20	10 48 56	44.54
	11 27 37	221.18	11 30 34	46.89
	11 40 24	222.75	11 33 53	47.48

Tethys–Rhea.

1899	Eastern M.T. (h m s)	p (°)	Eastern M.T. (h m s)	s (″)
April 16	16 10 1	105.70	16 25 49	46.46
	16 21 35	105.81	16 20 11	46.14
26	13 52 42	183.72	13 58 12	28.87
	14 5 42	185.60	14 1 44	29.41
	15 47 7	198.88	15 51 46	33.07
	15 57 11	200.34	15 54 16	33.12
30	15 1 57	151.64	15 6 40	60.44
	15 13 43	153.42	15 9 57	60.32
	15 57 19	160.04	16 2 7	57.48
	16 8 54	161.09	16 5 12	57.29
May 25	13 23 10	319.19	13 25 53	28.17
	13 29 42	319.50	13 27 35	28.35
	15 12 14	322.95	15 16 36	25.28
	15 21 4	324.56	15 18 35	25.59
28	13 7 17	259.65	13 10 51	30.78
	13 25 48	259.38	13 14 38	31.85
June 2	13 11 12	284.88	13 15 30	123.33
	13 22 15	285.35	13 18 52	123.20

Tethys–Rhea. — Cont.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s "
June 2	13 53 16	286.55	13 58 24	115.61
	14 7 49	287.23	14 3 58	115.05
	15 37 31	291.26	15 40 36	108.51
	15 45 18	291.67	15 43 12	108.16
3	12 2 51	60.52	12 6 58	42.29
	12 11 58	61.62	12 9 17	42.36
	13 34 16	65.32	13 39 2	41.32
	13 45 52	66.23	13 42 8	41.11
4	14 26 48	75.85	14 31 5	63.22
	14 38 47	76.40	14 34 52	63.56
	15 21 44	78.12	15 28 13	68.89
	15 35 4	78.62	15 31 24	68.43
18	14 47 30	113.11	14 51 6	103.77
	14 57 21	113.54	14 53 54	103.42
24	9 41 50	225.20	9 45 8	56.21
	9 51 26	225.60	9 50 58	56.49
	10 20 40	229.45	10 24 5	59.53
	10 28 53	230.65	10 26 54	59.45
	11 3 26	233.78	11 6 5	63.56
	11 10 58	234.30	11 8 19	63.52

Enceladus–Tethys.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s "
April 26	14 53 24	312.01	14 59 37	22.19
	15 14 6	315.61	15 3 57	22.23
May 25	13 37 6	82.76	13 41 40	65.71
	13 48 12	83.18	13 44 20	65.58
	15 26 32	90.99	15 31 4	68.50
	15 39 42	92.36	15 34 15	68.16
June 2	14 50 4	100.14	14 53 18	60.62
	14 59 0	100.54	14 56 6	60.17
3	11 38 48	285.22	11 42 18	76.47
	11 48 16	286.20	11 45 2	76.59
	13 3 22	291.96	13 8 12	70.55
	13 14 50	293.16	13 11 16	70.01
4	14 8 7	176.36	14 12 57	32.53
	14 22 56	182.05	14 15 58	32.61
18	13 4 18	282.56	13 6 54	78.91
	13 10 52	283.08	13 8 46	78.92
	13 33 45	285.00	13 36 19	76.84
	13 40 58	285.54	13 38 25	76.97
22	10 43 5	278.36	10 48 3	55.62
	10 55 35	279.58	10 51 14	55.24
26	10 19 52	303.54	10 24 0	9.12
	10 31 45	301.82	10 26 28	8.92
	11 38 57	305.44	11 42 36	10.07
	11 50 23	306.32	11 45 22	10.04

Enceladus–Rhea.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s "
April 26	15 27 46	233.44	15 33 36	27.68
	15 43 7	232.04	15 37 26	27.65

Enceladus–Rhea. — Cont.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s "
May 25	12 54 4	53.26	12 58 32	53.91
	13 5 18	54.71	13 4 10	54.20
	14 39 21	61.59	14 43 58	50.22
	14 51 6	63.41	14 46 58	50.73
June 2	14 30 52	298.59	14 35 4	54.38
	14 45 2	299.30	14 40 36	54.35
3	10 55 30	314.46	11 1 24	57.20
	11 10 34	315.40	11 4 36	56.77
	12 37 0	324.80	12 40 10	53.57
	12 46 24	325.94	12 42 47	53.52
4	13 10 6	103.87	13 17 22	67.77
	13 24 50	104.65	13 21 2	66.93
18	12 53 36	120.02	12 56 48	33.17
	13 2 6	119.14	12 59 12	33 38
	13 24 26	118.80	13 26 50	37.49
	13 31 30	118.26	13 28 51	37.65
	14 10 8	118.58	14 12 54	36.60
	14 18 18	117.28	14 15 1	36.21
22	10 32 14	95.07	10 35 54	50.54
	10 40 38	95.31	10 37 45	50.31
	11 16 3	95.17	11 18 50	48.50
	11 24 6	94.83	11 21 35	48.57
26	11 2 31	67.47	11 7 36	31.99
	11 15 24	66.29	11 11 16	31,65

Enceladus–Dione.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s "
May 25	12 31 50	238.85	12 36 30	18.11
	12 45 32	236.36	12 40 0	17.59
	14 5 40	241.79	14 10 27	22.32
	14 25 55	242.71	14 15 21	23.30
June 2	12 45 49	253.21	12 50 0	17.85
	12 55 52	253.10	12 52 11	17.16
3	11 14 19	298.84	11 24 22	61.20
	11 34 13	300.78	11 30 4	61.54
	12 49 30	309.30	12 53 30	55.28
	12 59 4	310.04	12 55 54	55.45
4	13 28 32	134.91	13 35 28	43.95
	13 44 22	136.48	13 39 42	43.90
18	12 38 16	221.90	12 42 6	29.23
	12 48 32	223.28	12 45 14	29.70
	13 15 8	226.86	13 17 59	29.59
	13 22 34	228.20	13 20 9	30.73
	13 55 40	233.73	13 59 28	30.72
	14 4 14	234.93	14 1 40	31.06
22	10 58 45	282.01	11 4 3	65.12
	11 11 7	283.04	11 6 47	65.00
26	11 19 31	137.32	12 24 58	44.61
	11 34 46	139.13	11 29 36	44.31

University of Virginia, 1899 *July* 1.

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No. 470.

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THE SECULAR PERTURBATIONS OF *VENUS*,

By ERIC DOOLITTLE.

The elements employed in this computation have been taken in each case from Dr. G. W. HILL'S "*New Theory of Jupiter and Saturn*." Those of the four inner planets are found on pages 192 and 554, of *Jupiter* and *Saturn* on page 558, of *Uranus* on page 109, and of *Neptune* on page 161. The mass $\frac{1}{22800}$ has, however, been assumed for *Uranus*.

The perturbations arising from the six inner planets have been published in the *Astronomical Journal*, Nos. 409, 428, 418, 434, 438 and 465. Those arising from *Neptune* were computed from the following elements:

Venus		*Neptune*	
$\pi =$	129° 27′ 42″.83	$\pi' =$	43° 17′ 30″.30
$i =$	3 23 35.01	$i' =$	1 47 1.68
$\Omega =$	75 19 53.08	$\Omega' =$	130 7 31.83
$e =$	0.006 84311	$e' =$	0.008 4962
$n =$	2106641″.357	$n' =$	7864″.935
$\log a =$	9.859 3378	$\log a' =$	1.478 1114
$m =$	$\frac{1}{408134}$	$m' =$	$\frac{1}{19700}$

Epoch = 1850.0 G.M.T.

The orbit of *Venus* was divided into eight parts with regard to the eccentric anomaly. This seems to be sufficient since, although as in previous cases the approximate tests are inapplicable during the greater part of the computation, yet the final sums are in reasonable agreement. The work has been duplicated from the beginning, and such proof-equations as were known have been applied. The values of the preliminary constants and of the principal auxiliary functions are as follows:

$I =$	2° 46′ 38″.369	$\log k =$	p9.999 9999
$II =$	265 47 34.23	$\log k' =$	p9.999 4896
$II' =$	179 34 46.34	$\log c =$	p8.814 7322
$K =$	86 12 46.11	$c =$	0.065 272791
$K' =$	86 12 49.67		

E	log r	v	A	log B	ϵ	h	[illegible]
°		° ′ ″			° ′ ″		
0	9.856 3557	0 0 0.00	904.778 43877	1.368 7855	67 3 55.97	904.17419	30.253 556
45	9.857 2313	45 16 40.52	904.512 60261	1.243 2687	112 20 54.31	904.17356	17.117 826
90	9.859 3378	90 23 31.50	904.392 37664	1.148 8820	174 45 43.90	904.17298	0.107 979
135	9.861 4342	135 16 35.65	904.488 20486	1.227 1626	239 0 2.70	904.17345	13.651 972
180	9.862 2996	180 0 0.00	904.743 93521	1.356 0070	285 56 45.18	904.17407	31.093 111
225	9.861 4342	224 43 24.35	905.009 71680	1.439 2863	323 8 57.81	904.17359	17.750 770
270	9.859 3378	269 36 28.50	905.129 94825	1.168 6184	356 51 56.49	904.17281	0.163 538
315	9.857 2313	314 43 19.48	905.034 14463	1.145 5844	30 30 49.35	904.17334	13.097 596
Σ_1	9.437 3309	540 0 0.00	3619.044 69887	5.342 2929	884 41 21.54	3616.69405	61.618 187
Σ_2	9.437 3310	720 0 0.00	3619.044 69890	5.355 3020	705 0 14.17	3616.69394	61.618 164

E	l	G	G'	G''	θ	$\log \mathfrak{K}$	$\log \mathfrak{L}$	$\log \mathfrak{N}$
°					° ′ ″			
0	0.53898	904.17415	0.595 2295	0.056 2134	1 32 17.018	0.000 23476	0.273 3 1127	0.1764 1378
45	0.27377	904.17354	0.330 9885	0.057 1984	1 11 14.024	0.000 13986	0.273 1 8776	0.1763 0105
90	0.15113	904.17298	0.154 8950	0.000 7710	0 45 6.502	0.000 05608	0.273 0 7605	0.1761 7538
135	0.24949	904.17343	0.299 8555	0.050 3537	1 7 39.561	0.000 12618	0.273 1 6951	0.1762 8052
180	0.50459	904.17403	0.565 4480	0.060 8462	1 30 28.921	0.000 22568	0.273 3 0217	0.1764 2976
225	0.77088	904.17357	0.795 5805	0.024 6764	1 43 33.466	0.000 29563	0.273 3 9543	0.1765 3468
270	0.89187	904.17281	0.892 0680	0.000 2028	1 48 0.658	0.000 32162	0.273 4 3007	0.1765 7365
315	0.79553	904.17332	0.813 3615	0.017 8097	1 41 14.706	0.000 29957	0.273 4 0068	0.1765 4059
Σ_1	2.08957	3616.69397	2.207 6405	0.118 0034	5 35 53.099	0.000 83814	1.093 1 2256	0.7056 2217
Σ_2	2.08967	3616.69386	2.239 7860	0.150 0382	5 46 41.757	0.000 86124	1.093 1 5338	0.7056 5684

E	log N	log P	log Q	log V	J'_1	J_2	J_3	F_2
0°	5.137 8654	9.498 6215	2.358 0297	2.357 9959	902.117 4996	+0.027 8169	−43.343 250	−165.19752
45	5.139 5214	9.500 1506	2.359 5431	2.359 5087	903.023 3587	+1.189 2143	−32.830 864	−124.26237
90	5.143 6916	9.504 2639	2.363 6151	2.363 6147	904.164 0829	+0.151 8779	− 2.911 684	− 9.86927
135	5.147 9185	9.508 5362	2.367 9231	2.367 8929	903.306 8137	−1.174 4691	+28.888 013	+110.97189
180	5.149 7409	9.510 4807	2.369 8895	2.369 8530	902.122 1024	−0.340 9776	+43.940 408	+167.47400
225	5.148 1063	9.508 9743	2.368 3773	2.368 3624	902.970 5135	+0.908 1699	+33.428 015	+126.53886
270	5.143 9578	9.504 8849	2.364 2800	2.364 2798	904.159 2634	+0.156 2063	+ 3.508 843	+ 12.14577
315	5.139 7097	9.500 5900	2.359 9901	2.359 9794	903.294 5923	−0.927 9474	−28.290 864	−108.69539
Σ_1	0.575 2556	8.018 2510	9.455 8143	9.455 7434	*3612.444 9449	−0.005 0765	+ 1.194 317	+ 4.55298
Σ_2	0.575 2558	8.018 2511	9.455 8336	9.455 7434	*3612.445 2400	−0.005 0323	+ 1.194 300	+ 4.55299

*The term in G'' has been removed in forming the sums.

E	F_3	1000 R_0	1000,000 S_0	1000 W_0	1000 $\frac{1}{a}$ sin E·$R^{(n)}$	1000,000·$\frac{1}{a}$ $S^{(n)}$
0°	+0.583 9042	0.006 821 434	−0.004 573 134	−0.000 988 3466	0.000 000 000	−0.006 365 877
45	−3.911 2736	0.006 867 470	+0.023 281 642	−0.000 751 3860	+0.006 746 065	+0.032 343 148
90	−0.477 7116	0.006 961 065	+0.003 193 229	−0.000 067 2756	+0.009 623 607	+0.004 414 608
135	+4.078 2664	0.007 008 255	−0.023 820 088	+0.000 674 0551	+0.006 818 058	−0.032 772 474
180	+0.600 1079	0.007 010 447	−0.002 565 237	+0.001 029 7346	0.000 000 000	−0.003 522 313
225	−4.007 3139	0.007 005 531	+0.025 294 517	+0.900 780 5505	−0.006 815 408	+0.034 801 040
270	−0.587 3116	0.006 967 370	+0.004 002 346	+0.000 081 1602	−0.009 632 323	+0.005 533 205
315	+3.989 3101	0.006 879 052	−0.024 698 966	−0.000 617 9491	−0.006 757 442	−0.034 312 118
Σ_1	+0.118 9889	0.027 760 316	+0.000 057 204	+0.000 055 2726	−0.000 008 716	+0.000 059 623
Σ_2	+0.118 9890	0.027 760 308	+0.000 057 105	+0.000 055 2705	−0.000 008 727	+0.000 059 596

E	1000 { R_0 sin v +(cos v+cos E) S_0 }	1000 { −R_0 cos v + $\left(\frac{r}{a}\sec^2\varphi+1\right)$ sin v S_0 }	1000 W_0 cos u	1000 W_0 sin u	−2000 $\frac{r}{a}$ R_0
0°	−0.000 009 1463	−0.006 821 4344	−0.000 579 11307	−0.000 800 91019	−0.013 549 511
45	+0.004 912 3773	−0.004 799 4176	+0.000 122 82960	−0.000 741 27847	−0.013 668 483
90	+0.006 960 8806	+0.000 054 0218	+0.000 054 78547	−0.000 039 04555	−0.013 922 131
135	+0.004 965 3747	+0.004 945 8425	−0.000 664 99046	−0.000 110 17258	−0.014 084 333
180	+0.000 005 1305	+0.007 010 4468	−0.000 603 36403	−0.000 834 44904	−0.014 116 841
225	−0.004 965 5471	+0.004 941 8261	+0.000 120 13897	−0.000 771 24930	−0.014 078 857
270	−0.006 967 2347	+0.000 039 6738	+0.000 065 44151	−0.000 048 00407	−0.013 934 740
315	−0.004 922 6067	−0.004 805 5578	−0.000 640 23059	−0.000 099 71443	−0.013 691 533
Σ_1	−0.000 010 3699	+0.000 282 7080	−0.001 062 25012	−0.001 722 40885	−0.055 523 223
Σ_2	−0.000 010 4018	+0.000 282 6932	−0.001 062 25248	−0.001 722 41478	−0.055 523 206

The equation $\sin q \cdot \frac{1}{2} A_1^{(s)} + \cos q \cdot B_0^{(c)} = 0$ is found to give the residual −0.000,000,000,000,0085. The values of the differential coefficients are as follows:

			log coeff.
$\left[\frac{de}{dt}\right]_{00} =$	− 0.005 469 6734″	m'	n7.737 9614
$\left[\frac{d\chi}{dt}\right]_{00} =$	+21.756 678	m'	p1.337 5926
$\left[\frac{di}{dt}\right]_{00} =$	− 0.559 45727	m'	n9.747 7669
$\left[\frac{d\Omega}{dt}\right]_{00} =$	−15.327 159	m'	n1.185 4617
$\left[\frac{d\pi}{dt}\right]_{00} =$	+21.729 810	m'	p1.337 0559
$\left[\frac{dL}{dt}\right]_{00} =$	−29.268 164	m'	n1.466 3954

If the above value of m' be adopted, there result the following values for the perturbations produced by *Neptune*:

$$\left[\frac{de}{dt}\right]_{00} = -0.000\,000\,277\,64841''$$

$$\left[\frac{d\chi}{dt}\right]_{00} = +0.001\,104\,4000$$

$$\left[\frac{di}{dt}\right]_{00} = -0.000\,028\,398\,849$$

$$\left[\frac{d\Omega}{dt}\right]_{00} = -0.000\,778\,02855$$

$$\left[\frac{d\pi}{dt}\right]_{00} = +0.001\,103\,0360$$

$$\left[\frac{dL}{dt}\right]_{00} = -0.001\,485\,6935$$

These results compare with those of LeVerrier and Newcomb as follows:

	Results of LeVerrier	Results of Newcomb	Method of Gauss
$\left[\frac{de}{dt}\right]_{00} =$	$0''.000\,00$	$0''.000\,00$	$-0''.000\,0003$
$e\left[\frac{d\pi}{dt}\right]_{00} =$	$+0.000\,01$	$+0.000\,01$	$+0.000\,0075$
$\left[\frac{di}{dt}\right]_{00} =$	$-0''.000\,036$	$-0''.000\,03$	$-0''.000\,0284$
$\sin i\left[\frac{d\Omega}{dt}\right]_{00} =$	$-0.000\,061$	$-0.000\,05$	$-0.000\,0461$

We may now express the variations which arise from the action of all of the disturbing planets by the following equations:

$$\left[\frac{de}{dt}\right]_{00} = -\,0''.095\,792\,466 - 0''.013\,01279u - 0''.018\,98299u'' - 0''.001\,963\,9882u''' - 0''.031\,162\,921u^{iv} - 0''.000\,675\,36338u^{v} + 0''.000\,005\,263\,3084u^{vi} - 0''.000\,000\,277\,64841u^{vii}$$

$$\left[\frac{d\chi}{dt}\right]_{00} = +\,0''.576\,2812 - 1''.189\,3992u - 5''.628\,9701u'' + 0''.745\,91759u''' + 6''.565\,4682u^{iv} + 0''.079\,351\,561u^{v} + 0''.002\,781\,7616u^{vi} + 0''.001\,104\,4000u^{vii}$$

$$\left[\frac{di}{dt}\right]_{00} = -\,0''.033\,057\,770 + 0''.009\,496\,5089u + 0''.000\,044\,940u'' + 0''.001\,320\,4280u''' - 0''.038\,659\,982u^{iv} - 0''.005\,232\,7048u^{v} + 0''.000\,001\,824\,038u^{vi} - 0''.000\,028\,398\,849u^{vii}$$

$$\left[\frac{d\Omega}{dt}\right]_{00} = -10''.061\,9223 + 0''.089\,773\,204u - 7''.293\,993u'' - 0''.017\,350\,446u''' - 2''.724\,2270u^{iv} - 0''.082\,465\,731u^{v} - 0''.002\,881\,2762u^{vi} - 0''.000\,778\,02855u^{vii}$$

$$\left[\frac{d\pi}{dt}\right]_{00} = +\,0''.558\,6460 - 1''.189\,2420u - 5''.641\,7558u'' + 0''.745\,86465u''' + 6''.560\,6924u^{iv} + 0''.079\,207\,000u^{v} + 0''.002\,776\,7109u^{vi} + 0''.001\,103\,0360u^{vii}$$

$$\left[\frac{dL}{dt}\right]_{00} = -10''.560\,6087 + 0''.745\,42525u - 5''.400\,5288u'' - 0''.099\,401\,2321u''' - 5''.534\,7410u^{iv} - 0''.264\,91624u^{v} - 0''.004\,960\,9570u^{vi} - 0''.001\,485\,6935u^{vii}$$

The quantities $u, u'', u''' \ldots$ are corrections to the masses adopted for *Mercury*, the *Earth*, *Mars*, etc., respectively, and are connected with the true masses m, m'', m''', etc., by the equations, $m = m_0(1+u)$, $m'' = m_0'(1+u'')$, $m''' = m_0'''(1+u''')$, etc.

LeVerrier has stated a similar system of equations, giving the values of dL, de, $ed\pi$, dp and dq ("*Annales de l'Observatoire de Paris*," Tome VI, page 6). By introducing the corrections necessary to bring the various masses employed by LeVerrier into accordance with those of Dr. Hill, and by making use of the elements of LeVerrier, we may obtain the differential coefficients given below. The results of Newcomb are obtained in a similar manner from the values stated in "*The Secular Variations of the Orbits of the Four Inner Planets*," page 376.

	Results of LeVerrier	Results of Newcomb	Method of Gauss
$\left[\frac{de}{dt}\right]_{00} =$	$-\,0''.095\,58$	$-\,0''.095\,76$	$-\,0''.095\,7925$
$\left[\frac{d\chi}{dt}\right]_{00} =$	$+\,0.554$	$+\,0.590$	$+\,0.576\,28$
$\left[\frac{di}{dt}\right]_{00} =$	$-\,0.033\,18$	$-\,0.033\,06$	$-\,0.033\,0578$
$\left[\frac{d\Omega}{dt}\right]_{00} =$	$-10.061\,6$	$-10.061\,8$	$-10.061\,922$
$\left[\frac{d\pi}{dt}\right]_{00} =$	$+\,0.536$	$+\,0.573$	$+\,0.558\,65$
$\left[\frac{dL}{dt}\right]_{00} =$	-10.519	....	$-10.560\,61$

The Flower Observatory, 1899 *July* 24.

OBSERVATIONS OF VARIABLE STARS,

By SIDNEY D. TOWNLEY.

[Communicated by the Director of Detroit Observatory.]

Observations of the variable 1582 *S Tauri*, made at the Washburn Observatory in 1891 and 1892, led me to suggest (*Publications of Washburn Observatory*, Vol. VI, part 3, page 32) that possibly the period of this star was only half that published in Chandler's Catalogue.

In order to settle the uncertainty, a series of observations, made with the 12½-inch equatorial telescope of the Detroit Observatory of the University of Michigan, was begun in 1896 October, and continued, except when interrupted by the nearness of the sun, until 1898 April. The obser-

vations decide decisively in favor of the longer period, as may be seen by plotting the observations given below.

The variable 1577 *R Tauri*, being almost in the same field with *S Tauri*, was observed also.

The magnitudes of the comparison-stars and an explanation of the methods and notations used, may be found in the publications above referred to.

From the curves of the plotted observations the following phases have been determined. The first three figures, 241, of the Julian date are omitted. The column O−C was derived from comparison of the observed phase with the elements as given in Chandler's Third Catalogue of Variable Stars (*A.J.* 379).

Results of Observations.

No.	Star	Phase	Mag.	Date Julian	Date Calendar	E	O−C
1577	*R Tauri*	Max.	8.8	3930	1897 Jan. 5	39	− 7
1577	*R Tauri*	Max.	8.7	4257	1897 Nov. 28	40	− 5
1582	*S Tauri*	Max.	9.1	3949	1897 Jan. 24	36	−24
1582	**S Tauri*	Max.	. .	4311	1898 Jan. 21	37	−38

* In obtaining this max. the curve above 10^M was assumed to be the same as in 1897 Jan. Uncertain.

THE REPSOLD TRANSIT-MICROMETER OF THE WASHBURN OBSERVATORY AND SLAT-SCREEN APPARATUS,[1]

By ALBERT S. FLINT.

References. For design and preliminary experiments: Repsold, *A.N.*, Bd. 123, s. 177. For accuracy of observation and diminution of personal equation: Becker, *A.N.*, Bd. 127, s. 185; Albrecht and Helmert, *Verhandlungen der internationalen Erdmessung*, 1890, pp. 21 and 71, and 1894, p. 177.

The transit-micrometer is at present in use upon the meridian-circle of 12.2 cm. aperture in a new series of observations for stellar parallaxes by the method of meridian transits. The essential feature of this instrument is an auxiliary screw which moves the eyepiece and is geared to the regular right-ascension screw, so that the eyepiece may be made to follow the movable thread. One revolution of the auxiliary screw makes three revolutions of the micrometer-screw, or an interval of 18.9 seconds at the equator. The auxiliary screw has a turning head at either side of the micrometer box, so that the observer can turn it by either hand alternately. Automatic signals are recorded on the chronograph by means of electric contact-points at each tenth of a revolution on a head adjacent to the regular micrometer-head. These points pass under a spring lever, which is held down by an adjusting screw. A long signal to mark a zero position is made by a contact point on the head which records the whole number of revolutions.

The lever has required somewhat frequent adjustment, but this may perhaps be remedied by applying a long spring, exerting its pressure directly above the point of contact. The spring should be adjusted by a hand screw with a head 1 cm. or more in diameter, and with the present lever the screw should have at least 50 threads to 1 cm. The turning handles are of celluloid and might better be finely milled for more secure hold when the observer's hands are cool and dry. Care should be taken to leave the slot in the cover plate large enough that the motion of the eyepiece may be perfectly free.

At first it is difficult for the observer to move the thread so as to keep it upon a star; but, after considerable practice, the present observer obtains for the probable error of a signal, under good conditions, $\pm 0^s.030$ for an equatorial star, the same as for a single thread when observing with a fixed reticule and chronograph. The method adopted in the present series of observations is to keep the space between two movable threads, about $0^s.70$, bisected by the star. Preliminary comparisons indicated no difference between this method and that of keeping the star on a single thread. When a star becomes too difficult for any reason, the observer should stop abruptly and regain bisection if desired by rapid movements which will leave no signals to cause confusion.

The performance of this transit micrometer in general has been very satisfactory. As shown by the experience of European observers, this device reduces the differences of personal equation between observers to a small fraction of their value under the old method, and it is expected that it will also avoid practically variations of personal equation in the same observer.

This instrument has also a device for recording bisections in declination for subsequent reading. A graduated head is placed beside the head of the ordinary declination

[1] Read before the Third Conference of Astronomers and Astrophysicists, Williams Bay, Wis., September, 1899.

micrometer, and a strip of paper is stretched between two rollers so that it may be moved along under the arc. A lever clamped to the axis of the micrometer travels between the arc and a similarly curved bar. The bar when pressed down by the observer, causes the lever to prick a plain mark upon the paper. This action also closes an electric circuit, so that the time is recorded on the chronograph. The extent of the arc is only 14″, so that the operation of the micrometer in a given position of the telescope is limited within this range. The head for turning the micrometer is at the end of a horizontal axis at the side of the micrometer-box opposite the head of the right-ascension screw, and is connected by bevel gears with the axis of the declination-screw. A mirror and lens over the arc enable the observer to read the record conveniently. The eyepiece has no motion in zenith-distance.

The graduated arc should be numbered at each division. When several bisections are made in the same position of the telescope, confusion of marks is liable to occur, even when the micrometer is set with a large inclination. The full advantage of the device is gained only when the marks may be read at leisure, as are the signals on the chronograph. As the strip of paper is liable to a little slip sidewise, a continuous zero should be maintained in some way, as by a fixed stylus pressed by a spring, or the micrometer head may be read off in addition for one bisection on each star.

The pricking device has been tried upon a number of stars and the probable error of a single mark found to be the same sensibly as that of a single bisection made in the ordinary manner.

The screw which moves the eyepiece may be detached from the right-ascension micrometer, and the pricking lever may be left unclamped from the declination micrometer, so that the whole may be reduced in its main features to the ordinary micrometer. It is not convenient, however, to have the usual number of fixed transit threads while making full employment of the movable thread.

The purpose of the slat screen apparatus, which was designed by Professor Comstock, is to diminish the apparent magnitude of bright stars by means of a simple attachment to the telescope itself such as to serve equally well at all zenith-distances. A frame of aluminium clamped to the objective end of the telescope holds a series of five parallel slats before the object-glass, each 25 mm. wide, and so placed as to be barely separate when lying in one plane. Each slat rotates upon its longitudinal axis, and all are connected by a rod, which is separate from them, but mounted upon short arms fixed to the axes of the slats and turning with them. Since there is no occasion to turn the slats through an angle of more than 90°, there is always a good leverage for turning the slats if the arms be fixed at the proper angle to the plane of the slats. For symmetry a similar rod is mounted on the other side of the frame. The slats and all pieces carried by the frame are also made of aluminum. The middle slat has a pulley attached to its axis, over which a wire cord passes to a second pulley secured to the telescope tube near the eye-end. Each branch of the cord contains a coil spring to equalize the tension. The weight of the entire apparatus is 27 oz. (0.76 kg.).

When the slats are wide open there is no appreciable deterioration of the star images, and with very bright stars the interference-pattern appears as a row of minute, sharp stellar points, about 2″ apart, extending to either side of the central image in a line at right angles to the direction of the slats. As the slats are turned the interference images at first become brighter and the line extends rapidly in a series of spectral images, while the central group remain in appearance as stellar points.

As at present employed the slats are set perpendicular to the meridian so that the line of interference-images is in line with the meridian; and the attention of the observer while maintaining bisection in right-ascension, has been kept upon the middle group of three or five images. A comparison of the transits of a number of faint stars observed with the slats wide open and of bright stars with the slats partly closed, shows no difference in the probable error of a single chronograph signal.

The operation of the apparatus is as simple as its construction, and it is confidently believed that it will prove the most satisfactory of screen-devices.

Washburn Observatory, Madison, Wis., 1899 Sept. 18.

DISCOVERY AND ELEMENTS OF A NEW VARIABLE STAR.

By R. T. A. INNES.

[Communicated by Dr. DAVID GILL, C.B., etc., H.M. Astronomer at the Cape of Good Hope.]

C. Z. XV^{h} 2254 = C.P.D. −54 6631.

$15^{h}\ 32^{m}\ 42^{s}$, $-54°\ 54'.1$ (1875).

Professor J. C. Kapteyn draws attention to this star in a list of stars suspected of variability which he forwarded to the Cape Observatory in December, 1896. He remarks:

"In Z. C. magnitude = 9.0
Magnitude according to measuring plate = 9.7
Magnitude according to check plate = 10.2"

My observations are:

	M			M	
1897 June 30	8.5	7 red	1898 Oct. 17	9.4	v. good
Aug. 12	9.2	7 red	21	8.8	good
25	9.35		1899 May 19	9.1	
Sept. 3	9.0	5 yel.	21	9.25	
17	9.0	8 red	25	8.8	
21	9.3	red	27	8.8	
Oct. 3	9.4		June 3	9.25	
11	9.3		6	8.8	
1898 Apr. 7	8.9	yel.	7	8.75	
15	8.75	red	9	8.75	
29	8.5	or. red	10	8.75	
May 2	8.9		11	8.75	
7	9.3		13	8.9	
15	8.9	red	13	9.05	
18	9.2		15	9.2	
21	8.9		18	8.8	
June 1	9.2		19	8.8	7 red
8	8.7		22	8.9	
10	9.1		24	8.85	
14	9.2		25	8.95	
18	8.6		26	9.2	
23	9.1		26	9.3	
25	9.3		26	9.2	
30	9.0		27	9.35	
July 9	9.2		29	9.1	7 red
15	8.8		30	8.95	
20	9.2		July 1	8.9	
25	8.8		2	8.9	
Aug. 6	8.8		4	8.75	
12	8.9				

For a long time I could not make anything of the observations, which at first were taken at too great an interval. The color of the star (7.1 on CHANDLER'S scale) and the lack of comparison-stars in the field of the 7-inch make the chance of error larger than usual, so that at times I was doubtful if all the variation shown was not due to errors of observation.

However, I picked out the most strongly marked minima, and found that they were well represented by a period of 12.68 days. Here is the comparison — rejecting the observation of 1897 Sept. 21, which is evidently erroneous.

Observed Min.	Calculated Min.	O – C
1897 Aug. 27	Adopted	..
Oct. 3	1897 Oct. 2.4	+0.6
14	15.1	–1.1
1898 May 7	1898 May 6.0	+1.0
18	18.6	–0.6
June 1	June 0.3	+0.7
14	13.0	+1.0
25	25.7	–0.7
July 9	July 8.4	+0.6
20	21.0	–1.0
Oct. 17	Oct. 17.8	–0.8
1899 May 21	1899 May 21.4	–0.4
June 3	June 3.0	0.0
15	15.7	–0.7
27.5	28.4	–0.9

My times of observation are about 8^h P.M., so that the epoch would be

1897 Aug. $27^d.25$ G.M.T.

and both O and C require therefore the addition of $0^d.25$ to the dates given.

Later on it will be possible to include the C.P.D. observations in a determination of the period.

The fall to and rise from minimum seem very sharp, but this star is hardly likely to be an *Algol*-variable.

The range of magnitude is from 8.7 to 9.3. My earlier observations showing a wider range, are not equal to later ones, as the 7-inch is now fitted with an eyepiece of larger field, affording better comparison-stars.

This star is in the field with Cape 1880, No. 8527, which I have recently found to be variable.

1899 *July* 5.

COMET *e* 1899.

A cable dispatch from Professor KREUTZ announces the discovery of a comet at Nice, by GIACOBINI, on Sept. 29, in the position for that date below. The second position given was also received from Professor KREUTZ, and the third from Professor KEELER (through Harvard College Observatory). This last is subject to some uncertainty from an inconsistency shown by the control-word.

Gr. M.T.	α	δ		
	h m s	° ′ ″		
1899 Sept. 29.313	16 26 32.	–5 10 –	Giacobini	Nice
Oct. 1.2767	16 31 0.7	–4 39 50	Cohn	Königsberg
2.6658	16 32 59.7	–4 12 18	Perrine	Mt. Hamilton

NOTES ON VARIABLE STARS, — No. 30.

BY HENRY M. PARKHURST.

W Leonis. Compared with elements in the Second Catalogue, derived from the original maximum observed by Dr. PETERS and my own observations from 1884 to 1891. Since that time it has remained invisible at the times of observation until this year. Reducing the period to 290 days, and making the periodic amplitude 40 days, will satisfy all my observations; but the amplitude may be much greater.

RESULTS OF OBSERVATIONS.

No.	Star	Phase	Observed Date Julian	Observed Date Calendar	E	Corr.	W	Mag.	Factors			Remarks
				1899							d	
2735	*U Can. Min.*	Max A	4692	Feb. 6	17	− 38	9	9.27	3.20	2.31	38	
"	"	Max B	4761	Apr. 16	17	+ 31	9	8.66	0.45	0.34	5	
2857	*U Puppis*	Max.	4763	Apr. 18	21	0	5	9.2	0.47	0.10	26	Sky uncertain
3060	*U Cancri*	Max.	4752	Apr. 7	55	+ 15	5	12.4	–	–	–	Very faint max.
3184	*T Hydrae*	Max.	4769	Apr. 24	52	+ 13	9	8.02	1.30	0.68	8	
3890	*W Leonis*	Max.	4589	Oct. 26	25	−104	1			–	–	1898. See note above
3994	*S Leonis*	Max.	4774.6	Apr. 29	74	− 57	9	10.30	1.16	1.34	27	Corr. still increasing
4315	*R Comae*	Max.	4867.6	July 31	69	− 0.4	9	8.88	0.65	0.82	7	El. *A.J.* 384. 415
4377	*T Virginis*	Max.	4808	June 2	41	− 2	9	8.38	0.65	1.10	19	
4407	*R Corvi*	Min.	4783	May 8	36	–	E	12.0	–	–		
4492	*Y Virginis*	Max A	4787	May 12	27	0	9	8.72	0.42	0.90	10	
"	"	Max B	4802	May 27	27	+ 15	9	8.45	0.28	0.40	10	
4573	*RU Virginis*	Max.	4661	Jan. 6	2	–	E	–	–		–	*A.J.* 415: period prob. less
4596	*U Virginis*	Max A	4750	Apr. 5	58	− 34	8	7.91	1.16	1.30	22	Corr. unchanged
"	"	Max B	4773	Apr. 28	58	− 11	2r	6.8	–	–	–	Highest obs.
4665	*RT Virginis*	Max.	4752	Apr. 7		–	7	8.12	1.02	0.81	25	Prob. period one year
4847	*S Virginis*	Max.	4850	July 14	16	+ 19	9	7.09	1.01	3.07	23	
4948	*R Can. Venat.*	Max.	4748	Apr. 3	12	− 26	1r	8.0	–	–	–	Highest obs. Prob. earlier
5037	*RR Virginis*	Max.	4836	June 30	31	− 25	5	11.37	–	–	–	Unusually bright
5070	*Z Virginis*	Max.	4910	Sept. 12	23	–	E	–	–	–	–	Probably late
5171	*RS Virginis*	Max.	4731	Mar. 17	9	− 19	1	8.1	–	–		Highest obs.
5194	*V Bootis*	Max.	4785	May 10	21	− 10	8	8.02	1.27	3.78	40	
5237	*R Bootis*	Max.	4810	June 4	67	− 1	9	7.23	1.11	0.80	26	
5249	*V Librae*	Min.	4838	July 2	25	–	E	13.3]	–	–	–	El. *A.J.* 444

INDIVIDUAL OBSERVATIONS.

Including Observations by ARTHUR C. PERRY

2735 *U Can. Min.*

(Continued from 350.)

Julian	Calendar	Mag.
	1898	
4640.5	Dec. 16	9.1
4642.6	18	9.35_2
	1899	
4657.6	Jan. 2	8.83_2
4665.5	10	9.73_2
4673.6	18	9.44_2
4687.6	Feb. 1	9.09_2
4696.5	10	9.58_2
4700.5	14	8.88_2
4705.5	19	9.68_2
4710.5	24	9.66_2
4721.5	Mar. 10	9.16;
4730.5	16	9.13_2
4737.5	23	9.07_2
4746.5	Apr. 1	9.14_2
4756.5	11	8.74_2
4757.5	12	8.48_2
4759.5	14	9.23_2
4760.5	15	8.38_2
4762.5	17	8.75_2

2735 *U Can. Min.*—Cont.

Julian	Calendar	Mag.
	1899	
4763.5	Apr. 18	8.46_2
4764.5	19	9.07_2
4765.5	20	8.95_2
4766.5	21	9.12_2

2857 *U Puppis.*

Julian	Calendar	Mag.
	1898	
4351.5	Mar. 5	11.2 :
4357.5	8	11.2 :
4358.5	9	11.2 :
4366.5	17	13.06
4393.5	Apr. 13	12.5]
4423.5	May 13	9.8]
	1899	
4715.5	Mar. 1	11.5]
4749.5	Apr. 4	10.82_2
4750.5	5	10.01_2
4756.6	11	9.71_2
4772.5	27	9.31_2
4775.5	30	11.11_2

3060 *U Cancri.*

(Continued from 441.)

Julian	Calendar	Mag.
	1899	
4690.5	Feb. 4	12.7]
4696.5	10	12.7]
4715.5	Mar. 1	12.7]
4743.5	29	12.7]
4744.5	30	12.66
4747.5	Apr. 2	12.40_2
4748.6	3	11]r
4755.5	10	12.46_2
4760.6	15	12.1
4772.6	27	12.5]
4773.6	28	12.0]r

3184 *T Hydrae.*

(Continued from 441.)

Julian	Calendar	Mag.
	1899	
4715.5	Mar. 1	10.3
4720.5	6	10.15
4728.6	14	10.00_2
4737.5	23	8.93_2
4746.5	Apr. 1	8.58_2

3184 *T Hydrae.*—Cont.

Julian	Calendar	Mag.
	1899	
4748.6	Apr. 3	9.2r
4750.5	5	8.69_2
4756.6	11	9.00_2
4762.5	17	8.03_2
4766.5	21	7.77_2
4767.5	22	8.39_2
4770.5	25	7.80_2
4771.5	26	8.02_2
4772.5	27	8.30_2
4773.6	Apr. 28	8.4r
4775.5	30	8.42_2
4779.6	May 4	8.2r

3890 *W Leonis.*

(Continued from 441.)

Julian	Calendar	Mag.
	1899	
4669.7	Jan. 14	10.1
4673.6	18	11.07_2
4687.6	Feb. 1	11.49_2

3994 *S Leonis.*

(Continued from 441.)

Julian	Calendar	Mag.
4719.6	Mar. 5	11.7]
4747.5	Apr. 2	11.18_2
4755.5	10	10.85_2
4760.6	15	10.83_2
4772.6	27	10.01;
4779.6	May 4	10.31_2
4781.5	9	10.59_2
4787.5	12	10.49_2
4790.6	15	10.51_2

4315 *R Comae.*

(Continued from 444.)

Julian	Calendar	Mag.
	1899	
4858.6	July 22	9.09_2
4862.6	26	9.15_2
4866.6	30	[illegible]
4867.6	31	8.98
4868.6	Aug. 1	8.63
4870.6	3	9.27_3
4871.6	4	8.73
4873.6	6	8.92_2

4377 *T Virginis.*

(Continued from 441.)

Julian	Calendar 1899		Mag
4747.5	Apr.	2	12]
4756.6		11	12]
4773.5		28	11.6
4774.5		29	11.35$_2$
4779.6	May	1	11.19$_2$
4784.6		9	9.83$_2$
4785.6		10	9.78$_2$
4786.6		11	9.99$_2$
4787.6		12	10.20$_2$
4790.6		15	9.52$_2$
4798.6	May	23	9.86
4799.6		24	9.87$_2$
4800.6		25	8.52$_2$
4801.6		26	8.73$_2$
4805.6		30	8.38$_2$
4810.6	June	4	7.78$_2$
4816.6		10	9.11$_2$
4823.6		17	8.56$_2$
4829.6		23	8.96$_2$

4407 *R Corvi.*

(Continued from 444.)

Julian	Calendar 1899		Mag
4757.6	Apr.	12	12]

4492 *Y Virginis.*

(Cont. from 441. Comp. Stars 415)

Julian	Calendar 1899		Mag.
4747.5	Apr.	2	11.71$_2$
4755.5		10	10.80$_2$
4757.6		12	11.03$_2$
4759.6		14	10.37$_2$
4760.6		15	10.97$_2$
4762.6		17	10.93$_2$

4492 *Y Virginis.* — Cont.

Julian	Calendar 1899		Mag.
4774.5	Apr.	29	9.60$_2$
4779.6	May	4	9.58$_2$
4784.6		9	8.72$_2$
4785.6		10	8.78$_2$
4786.6		11	8.71$_2$
4787.6		12	8.68$_2$
4790.6		15	8.56$_2$
4798.6		23	9.63$_2$
4799.6		24	8.78$_3$
4800.6		25	8.26$_2$
4801.6		26	8.31$_2$
4805.6		30	8.18$_2$
4810.6	June	4	9.11$_2$
4816.6		10	9.13$_2$
4822.6		16	10.29$_2$

4573 *RU Virginis.*

(Continued from 441.)

Julian	Calendar 1899		Mag.
4730.6	Mar.	16	10.0
4731.6		17	9.70$_2$
4741.6		30	9.79$_2$
4748.5	Apr.	3	9.81$_2$
4773.6		28	10.3P
4779.6	May	4	10.5P

4596 *U Virginis.*

(Continued from 444.)

Julian	Calendar 1899		Mag.
4730.6	Mar.	16	9.0
4731.5		17	9.03
4731.5		17	8.99
4744.6		30	7.73$_2$
4748.5	Apr.	3	8.04$_2$
4757.6		12	7.81$_2$
4759.6		14	8.03$_2$

4596 *U Virginis.* — Cont.

Julian	Calendar 1899		Mag.
4760.6	Apr.	15	8.29$_2$
4764.6		19	8.33$_2$
4773.6		28	6.8P
4779.6	May	1	6.9P

4665 *RT Virginis.*

(Continued from 444.)

Julian	Calendar 1899		Mag.
4730.6	Mar.	16	8.6
4731.5		17	8.48$_2$
4744.6		30	8.47$_2$
4748.5	Apr.	3	8.11$_2$
4748.6		3	8.4P
4757.6		12	7.91$_2$
4759.6		14	8.53$_2$
4760.6		15	8.53$_2$
4764.6		19	8.42$_2$
4774.6		29	8.7P

4847 *S Virginis.*

(Cont. from 441 Comp. Stars 384)

Julian	Calendar 1899		Mag.
4755.6	Apr.	11	12.4
4775.6		30	11.1
4787.6	May	12	11.44$_2$
4810.6	June	4	10.12$_2$
4817.6		11	9.98:
4822.6		16	10.13$_2$
4828.6		22	8.67$_2$
4835.6		29	7.87$_2$
4843.6	July	7	7.00$_2$
4850.6		14	7.00$_2$
4854.6		18	7.20$_2$
4858.6		22	7.11$_2$
4866.6		30	7.16$_2$
4874.5	Aug.	7	7.26$_2$

4918 *R Can. Venat.*

(Continued from 444.)

Julian	Calendar 1899		Mag.
4748.6	Apr.	3	8.1P
4774.6		29	9.1P
4779.6	May	5	9.0P
4836.6	June	30	10.1P
4839.6	July	3	10.4P

5037 *RR Virginis.*

(Continued from 444.)

Julian	Calendar 1899		Mag.
4773.5	Apr.	28	13.0]
4786.6	May	11	13.0]
4805.6		30	13.0]
4816.6	June	10	12.5:
4835.6		29	11.5
4836.6		30	11.27$_2$
4839.6	July	3	11.45$_2$
4845.6		9	11.86$_2$
4862.6		26	11.8:
4866.6		30	11.82$_2$

5070 *Z Virginis.*

(Continued from 384.)

1899

4773.6 Apr. 28 to
4847.6 July 11 12.3]
6 dates.

5174 *RS Virginis.*

(Continued from 415.)

Julian	Calendar 1899		Mag.
4731.6	Mar.	17	7.9
4748.6	Apr.	3	8.26$_2$
4757.6		12	8.82$_2$
4766.6		21	8.72$_2$
4786.6	May	11	9.18$_2$

5194 *V Bootis.*

(Cont. from 441 Comp. Stars 333)

Julian	Calendar 1899		Mag.
4770.6	Apr.	25	9.2
4774.6		29	7.99$_2$
4779.6	May	4	8.03$_2$
4785.6		10	7.96$_2$
4798.6		23	8.10$_2$
4816.7	June	10	8.19$_2$
4827.6		21	8.41$_2$

5237 *R Bootis.*

(Cont. from 444 Comp. Stars 333)

Julian	Calendar 1899		Mag.
4770.6	Apr.	25	8.9
4773.7		28	9.25$_2$
4779.6	May	4	9.21$_2$
4785.6		10	8.11$_2$
4798.6		23	7.27$_2$:
4807.6	June	1	7.47$_3$;
4808.6		2	7.02$_2$
4814.6		8	7.02$_3$
4822.6		16	8.02$_2$
4825.6		19	8.41$_2$
4836.6		30	8.6P

5249 *V Librae.*

(Cont. from 441 Comp. Stars 388)

1899

4773.6 Apr. 28 to
4866.6 July 30 13.3]
8 dates.

Comparison-Stars, 1893–1899.

2735 *U Can. Min.*

Star	DM.		Mag.	n
L	+8°1848		7.98	24
M	+8°1832		8.49	1
1N	+8°1842		8.77	25
2T	+8°1846		8.89	28
Z	+8°1847		10.67	6
a	5s3p	2T	10.43	9
c	6f	d	11.10	5
d	3f	a	11.23	8
h	3sf	d	12.18	2
i	3np	V	12.22	7
k	2np	V	12.46	6
l	1s	c	12.80	0

3994 *S Leonis.*

Star	DM.		Mag.	n
R	+6°2409		9.24	4
T	+6°2413		9.14	3
1T	+6°2414		9.38	5
X	+7°2424		10.20	3
Y	+7°2425		10.30	4
1Y	+7°2427		8.99	2
Z	+6°2411		10.35	25
a	14f	R	10.21	3
c	11s2f	R	10.78	24
d	17s1f	R	11.06	31
e	4s	a	10.72	3
g	2s3p	d	11.73	11

4377 *T Virginis.*

Star	DM.		Mag.	n
D	−4°3235		6.27	1
1I	−5°3463		7.52	4
J	−5°3465		7.31	14
N	−5°3459		8.23	17
R	−4°3250		8.87	2
X	−5°3458		10.28	22
Z	−5°3460		10.53	27
d	1n6p	Z	11.30	9
h	2n2p	V	11.62	5
j	6f	h	12.09	0
k	3f	h	12.17	0
l	3n1f	h	12.44	0

5037 *RR Virginis.*

Star	DM.		Mag.	n
C	−8°3689		6.53	9
D	−8°3696		6.50	11
I	−8°3693		8.06	24
W	−8°3686		10.51	4
X	−8°3694		10.62	13
1X	−8°3687		11.02	4
Z	−8°3695		11.35	13
d	6s3f	I	11.44	9
g	5s3f	j	11.94	8
h	2p	d	12.35	4
i	3s	g	12.29	7
j	3n6f	C	12.44	6

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ON THE INEQUALITIES IN THE LUNAR THEORY STRICTLY PROPORTIONAL TO THE SOLAR ECCENTRICITY,

By G. W. HILL.

This article is in continuation of that in *A.J.* No. 353, to which the reader is referred for the explanation of many of the symbols here used. I have there elaborated numerically the special case of the theory in which we have $e=0,\ \gamma=0,\ e'=0,$ the symbols having the signification DELAUNAY attributes to them.

In the further elaboration of the problem the order of the introduction of complexity into it is not indifferent. For it is plain that if, as the next step, we treat the case in which e' is to have a determinate value, but where still $e=0,\ \gamma=0,$ we shall not be troubled with considering the motions of the perigee and node. Also the subject will be more easily handled if we do not attempt to take account at once of terms of all dimensions with respect to e', but in succession of those of one, two, three, etc., dimensions. Probably it will not be necessary to go beyond the fourth dimension.

After this is done it will be possible to consider a lunar theory in which e has a determinate value, but in which still $\gamma=0$. The motion of the perigee must now be regarded, but that of the node need not yet be attended to. In like manner, as before, we divide the investigation so that terms severally proportional to $e,\ e^2,\ e^3,$ etc., may be separately considered.

Finally, the complete form of the lunar theory is elaborated, in which γ has a determinate value and the latitude of the moon is considered. Here it is necessary to notice the motions of both perigee and node. For a like reason as before we divide the work so that terms proportional to $\gamma,\ \gamma^2,\ \gamma^3,$ etc., may be separately obtained.

I.

In the former article it was supposed that the motion of the sun about the center of gravity of the earth and moon was circular, and we put

$$r'=a'(1+K)\quad,\quad \lambda'=\epsilon'+n't$$

Here we propose to take into account the eccentricity e' of this orbit, neglecting, however, all powers of this quantity above the first. The differential equations for the moon's coordinates are the same as before, but we now assume that

$$r'=a'(1+K)-a'e'\cos l'\quad,\quad \lambda'=\epsilon'+n't+2e'\sin l'$$

l' being the mean anomaly of the sun. Then the function R of the preceding article ought to be augmented by a quantity Z which is given by the equation

$$Z=-e'\cos l'\,.\,r'\frac{\partial R}{\partial r'}-2e'\sin l'\,.\,\frac{\partial R}{\partial\phi}$$

Employing here the rectangular coordinates $x,\ y$, let us suppose that R and Z are expressed in terms of them. In forming the equations to *variation* we employ the notation

$$\frac{\partial^2R}{\partial x^2}=H\quad,\quad\frac{\partial^2R}{\partial x\partial y}=J\quad,\quad\frac{\partial^2R}{\partial y^2}=K^*$$

and call the augmentations of the coordinates which are strictly proportional to e' by the designations $\delta x,\ \delta y$. These equations are then

$$\frac{d^2\delta x}{d\tau^2}=H\delta x+J\delta y+\frac{\partial Z}{\partial x}$$

$$\frac{d^2\delta y}{d\tau^2}=K\delta y+J\delta x+\frac{\partial Z}{\partial y}$$

In this particular case we no longer have the Jacobian integral in finite terms, but we may have it expressed by an infinite periodic series. Let us put

$$\frac{dM}{d\tau}=-e'\cos l'\,.\,\frac{d}{d\tau}\left[r'\frac{\partial R}{\partial r'}\right]-2e'\sin l'\,.\,\frac{d}{d\tau}\left[\frac{\partial R}{\partial\phi}\right]$$

Although M cannot be had in finite terms, nevertheless, as the right member is a known function of τ, this quantity is expressible by an infinite periodic series. Then the equation, which here takes the place of the Jacobian integral is

$$\frac{dx^2+dy^2}{2d\tau^2}-\mathrm{m}\frac{xdy-ydx}{d\tau}=R+M+C$$

* The reader is asked to discriminate the two uses of K.

In taking the variation of this equation we note that when the arbitrary constant C is developed in powers of e' only even powers present themselves; consequently $\delta C' = 0$. By putting

$$F = \frac{dx}{d\tau} + \mathrm{m}y \quad , \quad G = \frac{dy}{d\tau} - \mathrm{m}x$$

it is plain the variation of the last equation may be given the form

$$F\frac{d\delta x}{d\tau} + G\frac{d\delta y}{d\tau} - \frac{dF}{d\tau}\delta x - \frac{dG}{d\tau}\delta y = M$$

It is also evident that the quantities F, G, H, J, K satisfy the relations

$$\frac{d^2F}{d\tau^2} = HF + JG \quad , \quad \frac{d^2G}{d\tau^2} = KG + JF$$

In place of the unknowns δx, δy we propose to adopt ρ, σ such that

$$\delta x = F\rho \quad , \quad \delta y = G\sigma$$

The three equations to variation then become

$$\frac{d}{d\tau}\left[F^2\frac{d\rho}{d\tau}\right] + JFG\,(\rho - \sigma) = F\frac{\partial Z}{\partial x}$$

$$\frac{d}{d\tau}\left[G^2\frac{d\sigma}{d\tau}\right] + JFG\,(\sigma - \rho) = G\frac{\partial Z}{\partial y}$$

$$F^2\frac{d\rho}{d\tau} + G^2\frac{d\sigma}{d\tau} = M$$

of which the last is plainly a consequence of the first and second. For the sake of brevity employing the additional notation

$$L^2 = JFG \quad , \quad N = \tfrac{1}{2}\left(F\frac{\partial Z}{\partial x} - G\frac{\partial Z}{\partial y}\right)$$

and introducing a single new variable w to take the place of ρ and σ, the third equation to *variation* is satisfied by making

$$F^2\frac{d\rho}{d\tau} = \tfrac{1}{2}M + L\mathrm{w} \quad , \quad G^2\frac{d\sigma}{d\tau} = \tfrac{1}{2}M - L\mathrm{w}$$

From the first and second of the equations to *variation* we can obtain

$$\frac{d(L\mathrm{w})}{d\tau} + L^2\,(\rho - \sigma) = N$$

Dividing by L^2 and differentiating we get

$$\frac{d}{d\tau}\left[\frac{1}{L^2}\frac{d\,(L\mathrm{w})}{d\tau}\right] + \frac{d\rho}{d\tau} - \frac{d\sigma}{d\tau} = \frac{d}{d\tau}\left(\frac{N}{L^2}\right)$$

But

$$\frac{d\rho}{d\tau} - \frac{d\sigma}{d\tau} = \tfrac{1}{2}M\left(\frac{1}{F^2} - \frac{1}{G^2}\right) + L\left(\frac{1}{F^2} + \frac{1}{G^2}\right)\mathrm{w}$$

Substituting this in the preceding equation and putting

$$\Theta = J\left[\frac{F}{G} + \frac{G}{F}\right] - L\frac{d^2L^{-1}}{d\tau^2}$$

$$W = L\left[\frac{d}{d\tau}\left(\frac{N}{L^2}\right) - \tfrac{1}{2}M\left(\frac{1}{F^2} - \frac{1}{G^2}\right)\right]$$

the linear differential equation of the second order

$$\frac{d^2\mathrm{w}}{d\tau^2} + \Theta\mathrm{w} = W$$

is obtained for the determination of w.

The value of w resulting from the integration of this equation would have the general form

$$\mathrm{w} = AS + BT + V$$

A and B being the arbitrary constants. As S and T are periodic functions involving the mean anomaly of the moon, and as the solution we need ought not to have terms of this sort, it is necessary here to assume that $A = 0$, $B = 0$. Thus $\mathrm{w} = V$, where V contains only terms of the same periods as those occurring in W.

After w has thus been found we have

$$\delta x = F\int\frac{\frac{1}{2}M + L\mathrm{w}}{F^2}\,d\tau \quad , \quad \delta y = G\int\frac{\frac{1}{2}M - L\mathrm{w}}{G^2}\,d\tau$$

Here the two arbitrary constants must be so taken that δx and δy may have no terms independent of l', the mean anomaly of the sun. The variations of the coordinates usually adopted are then

$$\delta\left(\frac{a}{r}\right) = -\frac{a}{r^3}(x\delta x + y\delta y) \quad , \quad \delta\lambda = \frac{1}{r^2}(x\delta y - y\delta x)$$

II.

Although the preceding treatment constitutes a solution of the problem in an analytical sense, and possesses much elegance on account of the simplicity of the square of the velocity as expressed in terms of the differentials of the rectangular coordinates, it presents difficulties in practice when the quantities involved must be developed in infinite periodic series. The quantities F and G periodically vanish, which prevents the development of their reciprocals in infinite series. These difficulties can be overcome by putting the factor which makes the quantity vanish in evidence and executing the integration in accordance; the infinities then disappear. But the easier treatment is to have recourse to polar coordinates.

We adopt as variables for expressing the moon's position $\psi = \log r$, and ϕ. In order to avoid the writing it we suppose $a = 1$, and adopt the V of the preceding article. Then, supposing V and Z in terms of ψ and ϕ, the differential equations of motions are

$$\epsilon^{2\psi}\left[\frac{d^2\psi}{d\tau^2} + \frac{d\psi^2}{d\tau^2} - \frac{d\phi^2}{d\tau^2} - 2\mathrm{m}\frac{d\phi}{d\tau}\right] = \tfrac{1}{2}\frac{\partial V}{\partial\psi} + \frac{\partial Z}{\partial\psi}$$

$$\epsilon^{2\psi}\left[\frac{d^2\phi}{d\tau^2} + 2\frac{d\psi}{d\tau}\frac{d\phi}{d\tau} + 2\mathrm{m}\frac{d\psi}{d\tau}\right] = \tfrac{1}{2}\frac{\partial V}{\partial\phi} + \frac{\partial Z}{\partial\phi}$$

and the Jacobian integral

$$\epsilon^{2\psi}\frac{d\psi^2+d\phi^2}{d\tau^2} = V+2M$$

Let the increments of ψ and ϕ having e' as a factor be denoted by $\delta\psi$ and $\delta\phi$. To facilitate the investigation we can suppose the existence of two variables ρ and σ such that

$$\delta\psi = \frac{d\psi}{d\tau}\rho + \frac{d\phi}{d\tau}\sigma \qquad , \qquad \delta\phi = \frac{d\phi}{d\tau}\rho - \frac{d\psi}{d\tau}\sigma$$

It is very plain that the values, ρ = a constant, $\sigma = 0$, must satisfy the equations to *variation* which result from those of motion and their integral. Thus, when we obtain these equations expressed in terms of ρ and σ, in every case the factor multiplying ρ must vanish; we need not therefore go through the formality of deriving it. Hence, in making the transformation from $\delta\psi$, $\delta\phi$ to ρ, σ. we can limit ourselves to the expressions

$$\begin{aligned}
\delta\psi &= \frac{d\phi}{d\tau}\sigma \\
\delta\phi &= -\frac{d\psi}{d\tau}\sigma \\
\frac{d\delta\psi}{d\tau} &= \frac{d\psi}{d\tau}\frac{d\rho}{d\tau}+\frac{d\phi}{d\tau}\frac{d\sigma}{d\tau}+\frac{d^2\phi}{d\tau^2}\sigma \\
\frac{d\delta\phi}{d\tau} &= \frac{d\phi}{d\tau}\frac{d\rho}{d\tau}-\frac{d\psi}{d\tau}\frac{d\sigma}{d\tau}-\frac{d^2\psi}{d\tau^2}\sigma \\
\frac{d^2\delta\psi}{d\tau^2} &= \frac{d\psi}{d\tau}\frac{d^2\rho}{d\tau^2}+\frac{d\phi}{d\tau}\frac{d^2\sigma}{d\tau^2}+2\frac{d^2\psi}{d\tau^2}\frac{d\rho}{d\tau}+2\frac{d^2\phi}{d\tau^2}\frac{d\sigma}{d\tau}+\frac{d^3\phi}{d\tau^3}\sigma \\
\frac{d^2\delta\phi}{d\tau^2} &= \frac{d\phi}{d\tau}\frac{d^2\rho}{d\tau^2}-\frac{d\psi}{d\tau}\frac{d^2\sigma}{d\tau^2}+2\frac{d^2\phi}{d\tau^2}\frac{d\rho}{d\tau}-2\frac{d^2\psi}{d\tau^2}\frac{d\sigma}{d\tau}-\frac{d^3\psi}{d\tau^3}\sigma
\end{aligned}$$

In these expressions we can eliminate the second and third differentials of ψ and ϕ by means of the original equations of motion.

Subjecting the Jacobian integral to *variation* we find

$$\begin{aligned}
\epsilon^{2\psi}\left[\frac{d\psi}{d\tau}\frac{d\delta\psi}{d\tau}+\frac{d\phi}{d\tau}\frac{d\delta\phi}{d\tau}\right] &= V\frac{d\rho}{d\tau}+\epsilon^{2\psi}\left[\frac{d\psi}{\delta\tau}\frac{d^2\phi}{d\tau^2}-\frac{d\phi}{d\tau}\frac{d^2\psi}{d\tau^2}\right]\sigma \\
V\delta\psi &= V\frac{d\phi}{d\tau}\sigma \\
-\tfrac{1}{2}\,\delta V &= \tfrac{1}{2}\left[\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}-\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}\right]\sigma
\end{aligned}$$

The sum of these three equations gives the *variation* of the Jacobian integral.

But we have

$$\epsilon^{2\psi}\left[\frac{d\psi}{d\tau}\frac{d^2\phi}{d\tau^2}-\frac{d\phi}{d\tau}\frac{d^2\psi}{d\tau^2}\right] = \tfrac{1}{2}\left[\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}-\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}\right]-V\left(\frac{d\phi}{d\tau}+2\mathrm{m}\right)$$

Consequently the equation to *variation* derived from the Jacobian integral is

$$V\frac{d\rho}{d\tau}+\left[\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}-\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}-2\mathrm{m}\,V\right]\sigma = M$$

or, if we put

$$A_1 = \frac{1}{V}\left[\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}-\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}\right]+2\mathrm{m}$$

it will take the form

$$\frac{d\rho}{d\tau} = A_1\sigma+\frac{M}{V}$$

It is necessary to derive still another equation to *variation* from the original equations of motion. Then, if we take the *variations* of both and multiply the first by $\frac{d\phi}{d\tau}$ and the second by $-\frac{d\psi}{d\tau}$, it is plain from the equivalents we have given for $\frac{d^2\delta\psi}{d\tau^2}$ and $\frac{d^2\delta\phi}{d\tau^2}$, that not only does the term in ρ vanish, but also the term in $\frac{d^2\rho}{d\tau^2}$. Consequently the resulting equation will be of the form

$$A\frac{d^2\sigma}{d\tau^2}+B\frac{d\rho}{d\tau}+C\frac{d\sigma}{d\tau}+D\sigma = N$$

We can eliminate $\frac{d\rho}{d\tau}$ from this by means of the last equation, and thus shall have a linear equation of the second order for the determination of σ.

Proceeding to the derivation of this equation to *variation*, we divide the somewhat complex mass of terms into four parts.

1. Make the second derivatives in the equations alone to vary and we get the terms

$$\text{(I)}\quad V\frac{d^2\sigma}{d\tau^2}+V\left[A_1+2\left(\frac{d\phi}{d\tau}+\mathrm{m}\right)\right]\frac{d\rho}{d\tau}+\left[\frac{dV}{d\tau}-2V\frac{d\psi}{d\tau}\right]\frac{d\sigma}{d\tau} + \epsilon^{2\psi}\left[\frac{d\psi}{d\tau}\frac{d^3\psi}{d\tau^3}+\frac{d\phi}{d\tau}\frac{d^3\phi}{d\tau^3}\right]\sigma$$

But by differentiating the equations of motion it results that

$$\epsilon^{2\psi}\left[\frac{d\psi}{d\tau}\frac{d^3\psi}{d\tau^3}+\frac{d\phi}{d\tau}\frac{d^3\phi}{d\tau^3}\right] = -2V\frac{d^2\psi}{d\tau^2}-\mathrm{m}V\left[A_1+2\left(\frac{d\phi}{d\tau}+\mathrm{m}\right)\right] - \frac{dV}{d\tau}\frac{d\psi}{d\tau}+\tfrac{1}{2}\left[\frac{\partial^2 V}{\partial\psi^2}\frac{d\psi^2}{d\tau^2}+2\frac{\partial^2 V}{\partial\psi\,\partial\phi}\frac{d\psi d\phi}{d\tau^2}+\frac{\partial^2 V}{\partial\phi^2}\frac{d\phi^2}{d\tau^2}\right]$$

2. By making only the first derivatives in the equations to vary we get the terms

$$\text{(II)}\quad -2V\left(\frac{d\phi}{d\tau}+\mathrm{m}\right)\frac{d\rho}{d\tau}+2V\frac{d\psi}{d\tau}\frac{d\sigma}{d\tau} + V\left[A_1+2\left(\frac{d\phi}{d\tau}+\mathrm{m}\right)+2\frac{d^2\psi}{d\tau^2}\right]\sigma$$

3. By making only the common factor $\epsilon^{2\psi}$ of the two equations to vary we get the terms

$$\text{(III)}\qquad V\left[A_1-2\mathrm{m}\right]\frac{d\phi}{d\tau}\sigma$$

4. In fine, by making only the second members of the equations to vary we get the terms

$$\text{(IV)} \qquad -\tfrac{1}{2}\left[\frac{\partial^2 V}{\partial\psi^2}\frac{d\phi^2}{d\tau^2}-2\frac{\partial^2 V}{\partial\psi\partial\phi}\frac{d\psi d\phi}{d\tau^2}+\frac{\partial^2 V}{\partial\phi^2}\frac{d\psi^2}{d\tau^2}\right]\sigma$$

By adding these four divisions of terms we arrive at the equation

$$\frac{d}{d\tau}\left[V\frac{d\sigma}{d\tau}\right]+V A_1\frac{d\rho}{d\tau}+\left[\tfrac{1}{2}\left(\frac{\partial^2 V}{\partial\psi^2}-\frac{\partial^2 V}{\partial\phi^2}-2\frac{\partial V}{\partial\psi}\right)\frac{d\psi^2-d\phi^2}{d\tau^2}+2\left(\frac{\partial^2 V}{\partial\psi\partial\phi}-\frac{\partial V}{\partial\phi}\right)\frac{d\psi d\phi}{d\tau^2}\right]\sigma$$
$$=\frac{\partial Z}{\partial\psi}\frac{d\phi}{d\tau}-\frac{\partial Z}{\partial\phi}\frac{d\psi}{d\tau} = N$$

No symmetry is apparent in the coefficient of σ as written in this equation, but it may be given the following form:

$$-\left[\frac{\partial V}{\partial\psi}\frac{d\psi}{d\tau}+\frac{\partial V}{\partial\phi}\frac{d\phi}{d\tau}\right]\frac{d\psi}{d\tau}+\tfrac{1}{2}\left[\frac{\partial^2 V}{\partial\psi^2}\frac{d\psi^2}{d\tau^2}+2\frac{\partial^2 V}{\partial\psi\partial\phi}\frac{d\psi}{d\tau}\frac{d\phi}{d\tau}+\frac{\partial^2 V}{\partial\phi^2}\frac{d\phi^2}{d\tau^2}\right]$$
$$+\left[\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}-\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}\right]\frac{d\phi}{d\tau}-\tfrac{1}{2}\left[\frac{\partial^2 V}{\partial\psi^2}\frac{d\phi^2}{d\tau^2}-2\frac{\partial^2 V}{\partial\psi\partial\phi}\frac{d\psi}{d\tau}\frac{d\phi}{d\tau}+\frac{\partial^2 V}{\partial\phi^2}\frac{d\psi^2}{d\tau^2}\right]$$

Eliminating $\frac{d\rho}{d\tau}$ from the equation by means of the value given by the equation to *variation* derived from the Jacobian integral we have

$$\frac{d}{d\tau}\left[V\frac{d\sigma}{d\tau}\right]+\left[\tfrac{1}{2}\left(\frac{\partial^2 V}{\partial\psi^2}-\frac{\partial^2 V}{\partial\phi^2}-2\frac{\partial V}{\partial\psi}\right)\frac{d\psi^2-d\phi^2}{d\tau^2}+2\left(\frac{\partial^2 V}{\partial\psi\partial\phi}-\frac{\partial V}{\partial\phi}\right)\frac{d\psi d\phi}{d\tau^2}+V A_1^2\right]\sigma = N - A_1 M$$

In order to reduce this equation to the simplest possible form we introduce a new variable w such that

$$\sigma = V^{-\frac{1}{2}}\,\mathrm{w}$$

If we put Q for the coefficient of σ in the equation before $\frac{d\rho}{d\tau}$ was eliminated we have the equation

$$\frac{d^2\mathrm{w}}{d\tau^2}+\frac{1}{V}\left[Q+VA_1^2+\tfrac{1}{4}\frac{1}{V}\frac{dV^2}{d\tau^2}-\tfrac{1}{2}\frac{d^2V}{d\tau^2}\right]\mathrm{w} = \frac{N-A_1M}{\sqrt{V}}$$

But

$$\tfrac{1}{2}\frac{d^2V}{d\tau^2}=\tfrac{1}{2}\left[\frac{\partial^2 V}{\partial\psi^2}\frac{d\psi^2}{d\tau^2}+2\frac{\partial^2 V}{\partial\psi\partial\phi}\frac{d\psi d\phi}{d\tau^2}+\frac{\partial^2 V}{\partial\phi^2}\frac{d\phi^2}{d\tau^2}\right]+\tfrac{1}{2}\left[\frac{\partial V}{\partial\psi}\frac{d^2\psi}{d\tau^2}+\frac{\partial V}{\partial\phi}\frac{d^2\phi}{d\tau^2}\right]$$
$$=\tfrac{1}{2}\left[\frac{\partial^2 V}{\partial\psi^2}\frac{d\psi^2}{d\tau^2}+2\frac{\partial^2 V}{\partial\psi\partial\phi}\frac{d\psi d\phi}{d\tau^2}+\frac{\partial^2 V}{\partial\phi^2}\frac{d\phi^2}{d\tau^2}\right]-\tfrac{1}{2}\left[\frac{\partial V}{\partial\psi}\frac{d\psi}{d\tau}+\frac{\partial V}{\partial\phi}\frac{d\phi}{d\tau}\right]\frac{d\psi}{d\tau}$$
$$+\tfrac{1}{2}\left[\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}-\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}\right]\left(\frac{d\phi}{d\tau}+\mathrm{m}\right)+\tfrac{1}{4}\,\epsilon^{-2\psi}\left[\frac{\partial V^2}{\partial\psi^2}+\frac{\partial V^2}{\partial\phi^2}\right]$$

$$\tfrac{1}{4}\,VA_1^2=\frac{1}{4V}\left[\frac{\partial V^2}{\partial\psi^2}\frac{d\phi^2}{d\tau^2}-2\frac{\partial V}{\partial\psi}\frac{\partial V}{\partial\phi}\frac{d\psi d\phi}{d\tau^2}+\frac{\partial V^2}{\partial\phi^2}\frac{d\psi^2}{d\tau^2}\right]+\mathrm{m}\left[\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}-\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}\right]+\mathrm{m}^2V$$

$$\tfrac{1}{4}\frac{1}{V}\frac{dV^2}{d\tau^2}=\frac{1}{4V}\left[\frac{\partial V^2}{\partial\psi^2}\frac{d\psi^2}{d\tau^2}+2\frac{\partial V}{\partial\psi}\frac{\partial V}{\partial\phi}\frac{d\psi d\phi}{d\tau^2}+\frac{\partial V^2}{\partial\phi^2}\frac{d\phi^2}{d\tau^2}\right]$$

By the assistance of these expressions we obtain the equation

$$Q+\tfrac{1}{4}\,VA_1^2+\tfrac{1}{4}\frac{1}{V}\frac{dV^2}{d\tau^2}-\tfrac{1}{2}\frac{d^2V}{d\tau^2} = -\tfrac{1}{2}\left[\frac{\partial V}{\partial\psi}\frac{d\psi}{d\tau}+\frac{\partial V}{\partial\phi}\frac{d\phi}{d\tau}\right]\frac{d\psi}{d\tau}+\tfrac{1}{2}\left[\frac{\partial V}{\partial\psi}\frac{d\phi}{d\tau}-\frac{\partial V}{\partial\phi}\frac{d\psi}{d\tau}\right]\frac{d\phi}{d\tau}$$
$$-\tfrac{1}{2}\left[\frac{\partial^2 V}{\partial\psi^2}\frac{d\phi^2}{d\tau^2}-2\frac{\partial^2 V}{\partial\psi\partial\phi}\frac{d\psi d\phi}{d\tau^2}+\frac{\partial^2 V}{\partial\phi^2}\frac{d\psi^2}{d\tau^2}\right]+\mathrm{m}^2V$$

Consequently, if we put

$$A_2 = -\frac{1}{2V}\left[\left(\frac{\partial^2 V}{\partial\psi^2}-\frac{\partial V}{\partial\psi}\right)\frac{d\phi^2}{d\tau^2}-2\left(\frac{\partial^2 V}{\partial\psi\partial\phi}-\frac{\partial V}{\partial\phi}\right)\frac{d\psi d\phi}{d\tau^2}+\left(\frac{\partial^2 V}{\partial\phi^2}+\frac{\partial V}{\partial\psi}\right)\frac{d\psi^2}{d\tau^2}\right]+\mathrm{m}^2$$

$$\Theta = \tfrac{3}{4}A_1^2+A_2$$

$$W = \frac{N-A_1M}{\sqrt{V}}$$

the equation determining w is

$$\frac{d^2\mathrm{w}}{d\tau^2}+\Theta\mathrm{w} = W$$

Attending to the integration of this we put

$$\mathrm{w} = \Sigma\,\mathrm{b}_i\cos(l'+i\tau)\quad,\quad W = \Sigma\,W_i\cos(l'+i\tau)\ ,$$
$$\Theta = \Sigma\,\Theta_i\cos i\tau$$

These summations are extended from $i=-\infty$ to $i=+\infty$, and, in the last equation we have $\Theta_{-i}=\Theta_i$. Thus, for the determination of the unknown coefficients b_i, we have the group of linear equations represented generally by

$$-(j+\mathrm{m})^2\,\mathrm{b}_j+\Sigma\,.\,\Theta_i\,\mathrm{b}_{j-i} = W_j$$

For the degree of approximation we wish to attain it is necessary to go from b_{-10} to b_{10}; thus we have 21 equa-

tions with 21 unknowns. These we solve by steps of approximation. First we limit ourselves to the 5 unknowns from b_{-2} to b_2 and the 5 equations which specially determine them; afterwards, with these values, it is easy to obtain values of the remaining unknowns to the corresponding degree of approximation. With these values the final terms of the 5 equations may be corrected and the operation of solution repeated. About three repetitions of this procedure suffice to obtain the desired degree of precision.

III.

In reducing the preceding results to numbers we employ the values of the constants given in the former article. We there gave the values of $\frac{a}{r}$ and ϕ for every 15° in the semi-circumference of the argument τ. The expression for $\frac{1}{2}V$ being

$$\begin{aligned}\tfrac{1}{2}V = C + (1+\mathrm{m})^2\frac{a}{r} + \tfrac{1}{2}\mathrm{m}^2\frac{r^2}{a^2} &+ \alpha_1\frac{r^2}{a^2}\left[\tfrac{3}{4}\cos 2\phi + \tfrac{1}{4}\right]\\ &+ \alpha_2\frac{r^3}{a^3}\left[\tfrac{5}{8}\cos 3\phi + \tfrac{3}{8}\cos\phi\right]\\ &+ \alpha_3\frac{r^4}{a^4}\left[\tfrac{35}{64}\cos 4\phi + \tfrac{5}{16}\cos 2\phi + \tfrac{9}{64}\right]\\ &+ \alpha_4\frac{r^5}{a^5}\left[\tfrac{63}{128}\cos 5\phi + \tfrac{35}{128}\cos 3\phi + \tfrac{15}{64}\cos\phi\right]\end{aligned}$$

for facilitating the computation of special values of this function and its several partial derivatives with respect to r, r' and ϕ, we give the following tables of the values of its several terms:

τ	$(1+\mathrm{m})^2\left(\frac{a}{r}-1\right)$	$\frac{1}{2}\mathrm{m}^2\frac{r^2}{a^2}$	$\frac{3}{4}\alpha_1\frac{r^2}{a^2}\cos 2\phi$	$\frac{1}{4}\alpha_1\frac{r^2}{a^2}$	$\frac{5}{8}\alpha_2\frac{r^3}{a^3}\cos 3\phi$
0°	+917 68107 2 [11]	+321 75273 1 [11]	+482 62760 36 [12]	+160 87586 76 [12]	+1 00211 19 [12]
15	803 54383 9	322 37745 1	416 34669 54	161 18822 54	+ 69995 23
30	494 00132 3	324 08088 3	+235 80106 01	162 03993 89	— 2606 91
45	+ 76 72033 2	326 39865 9	— 9 57873 67	163 19882 30	74193 68
60	—333 46944 1	328 70136 5	253 56129 83	164 35017 28	1 03443 01
75	627 27574 9	330 36573 4	431 35825 30	165 18235 45	72727 17
90	728 23916 4	330 94059 6	496 40898 06	165 46978 45	— 192 20
105	609 52328 6	330 26481 1	431 80183 08	165 13189 30	+ 72428 55
120	—299 36347 7	328 50897 5	254 30444 60	164 25397 80	1 03343 56
135	+124 57742 0	326 13157 8	— 10 40897 12	163 06528 30	74582 34
150	552 13811 3	323 75992 5	+235 05589 87	161 87946 01	+ 2785 70
165	867 98717 5	322 02450 5	415 73832 07	161 01175 27	— 69813 25
180	+984 24369 5	+321 38924 9	+482 08237 79	+160 69412 59	—1 00041 43

τ	$\frac{3}{8}\alpha_2\frac{r^3}{a^3}\cos\phi$	$\frac{35}{64}\alpha_3\frac{r^4}{a^4}\cos 4\phi$	$\frac{5}{16}\alpha_3\frac{r^4}{a^4}\cos 2\phi$	$\frac{9}{64}\alpha_3\frac{r^4}{a^4}$	$\frac{63}{128}\alpha_4\frac{r^5}{a^5}\cos 5\phi$	$\frac{35}{128}\alpha_4\frac{r^5}{a^5}\cos 3\phi$	$\frac{15}{64}\alpha_4\frac{r^5}{a^5}\cos\phi$
0°	+60126 71 [12]	+221 23 [12]	+126 12 [12]	+56 89 [12]	+50 [12]	+28 [12]	+24 [12]
15	58168 61	+107 18	109 27	57 11	+12	+20	23
30	52374 80	—118 82	+ 62 21	57 71	—45	— 1	21
45	43013 14	227 49	— 2 55	58 54	—35	—21	17
60	30596 28	—108 76	67 85	59 37	+28	—29	12
75	15920 21	+120 21	116 01	59 97	+51	—21	+ 7
90	+ 38 44	231 01	133 74	60 18	0	0	0
105	—15841 42	+121 08	116 09	59 94	—51	+21	— 6
120	30512 44	—107 77	68 01	59 30	—29	+29	12
135	42922 81	227 08	— 2 76	58 45	+35	+21	17
150	52278 46	—119 04	+ 61 95	57 60	+45	+ 1	21
165	58068 18	+106 71	108 99	56 98	—12	—19	23
180	—60024 86	+220 73	+126 13	+56 76	—50	—28	—24

τ	$-\frac{3}{2}a_1\frac{r^2}{a^2}\sin 2\phi$	$-\frac{15}{8}a_2\frac{r^3}{a^3}\sin 3\phi$	$-\frac{3}{8}a_2\frac{r^3}{a^3}\sin\phi$	$-\frac{35}{16}$ ··	$-\frac{5}{8}$ ··	$-\frac{315}{128}$ ··	$-\frac{105}{128}$ ··	$-\frac{15}{64}$ ··
°	11	11	11	11	11	11	11	11
15	−491 89521 3	−2 16365 5	−15897 5	−7780	−129 1	−25	−6	−1
30	850 20076 8	3 03801 8	30840 7	−761 6	224 3	−12	9	1
45	979 00551 6	−2 10733 7	43863 1	+ 35 6	260 1	+19	−6	2
60	845 70794 4	+ 77092	54022 3	814 7	226 3	+22	0	2
75	487 83993 1	2 24124 0	60497 4	799 4	131 2	− 8	+6	2
90	− 1 21698 6	3 13601 7	62720 4	+ 2 3	− 3	27	9	3
105	+485 65631 7	2 24793 4	60188 5	−796 7	+130 6	− 8	+6	2
120	844 14115 4	+ 8684 2	54007 1	815 5	225 7	+22	0	2
135	978 17019 3	−2 09900 7	43846 0	− 38 7	260 3	+19	−6	2
150	849 92555 2	3 03336 0	30826 4	+759 0	224 0	−12	8	1
165	+491 87278 5	−2 16205 3	−15889 5	+776 9	+128 9	−24	−6	−1

τ	$\log\frac{d\psi}{d\tau}$	$\log\frac{d\phi}{d\tau}$	τ	$\log\frac{d\psi}{d\tau}$	$\log\frac{d\phi}{d\tau}$
0°	. . . . .	0.00859 82784	105°	7.8663 1621n	9.99236 04082
15	7.8590 4872	0.00710 23642	120	8.0993 3173n	9.99564 41626
30	8.0940 2940	0.00414 82420	135	8.1629 8202n	0.00011 68426
45	8.1511 7491	9.99973 58223	150	8.1032 1855n	0.00460 21576
60	8.0818 5997	9.99536 74425	165	7.8669 8852n	0.00789 81733
75	7.8314 6683	9.99221 44191	180	. . . . .	0.00910 75964
90	6.4712 7940n	9.99111 30885			

Where it is necessary the order of the last decimal is expressed by the small figures at the top of the column. In order to have the special values of the various derivatives of $\frac{1}{2}V$, correspondent to the indicated values of τ, it is necessary only to multiply the quantities given in the preceding tables by certain positive or negative integers, in all cases less than 25 (their values are perceived at a glance) and sum the products. In this way have been formed the following values of Δ_1, Δ_2 and Θ:

τ	Δ_1	Δ_2	Θ
0°	−2.14482 69404 8	−2.40513 46257 4	1.04507 73277 1
15	2.14686 78054 4	2.39669 23142 2	1.06008 87163 1
30	2.15260 71888 3	2.37396 30611 0	1.10132 52209 1
45	2.16083 67957 6	2.34370 65632 7	1.15820 51801 6
60	2.16952 31500 4	2.31438 96004 2	1.21573 34234 9
75	2.17619 04936 5	2.29363 64155 1	1.25821 73830 0
90	2.17875 27123 2	2.28650 95831 7	1.27371 29529 9
105	2.17640 68220 4	2.29472 39660 8	1.25783 60251 8
120	2.17000 52862 7	2.31645 86141 2	1.21523 35926 8
135	2.16163 95914 4	2.34656 95375 1	1.15794 47549 4
150	2.15373 42653 2	2.37739 03147 5	1.10153 81494 8
165	2.14823 94105 1	2.40044 88286 3	1.06075 05950 0
180	−2.14628 96921 7	−2.40899 82779 1	1.04592 13041 6

From the special values of Θ is derived the following periodic series representing it, which may be compared with that given in the memoir "On the Motion of the Lunar Perigee."* The differences are due to the inclusion here of terms dependent on $\frac{a}{a'}$ and μ:

$$\Theta = \left\{\begin{array}{lrl} & 1.15884\,04425 & \\ - & 11\,88248 & \cos\tau \\ - & 11408\,84846 & \cos 2\tau \\ - & 30\,72745 & \cos 3\tau \\ + & 76\,55834 & \cos 4\tau \\ + & 42061 & \cos 5\tau \\ - & 1\,83319 & \cos 6\tau \\ - & 966 & \cos 7\tau \\ + & 1085 & \cos 8\tau \\ + & 15 & \cos 9\tau \\ - & 20 & \cos 10\tau \end{array}\right\}$$

* *Acta Mathematica*, Vol. VIII, p. 34.

Attending next to the determination of M we obtain

$$\frac{dM}{d\tau} = -\left\{\begin{array}{lrl} & 0.00003\,87849 & \sin \tau \\ + & 2922\,21996 & \sin 2\tau \\ + & 10\,80772 & \sin 3\tau \\ + & 17\,81067 & \sin 4\tau \\ + & 8725 & \sin 5\tau \\ + & 12406 & \sin 6\tau \\ + & 70 & \sin 7\tau \\ + & 91 & \sin 8\tau \\ + & 1 & \sin 9\tau \\ + & 1 & \sin 10\tau \end{array}\right\} e' \cos l' + \left\{\begin{array}{lrl} & 0.00002\,89353 & \cos \tau \\ + & 3914\,43255 & \cos 2\tau \\ + & 16\,51032 & \cos 3\tau \\ + & 23\,79574 & \cos 4\tau \\ + & 13207 & \cos 5\tau \\ + & 16565 & \cos 6\tau \\ + & 106 & \cos 7\tau \\ + & 122 & \cos 8\tau \\ + & 1 & \cos 9\tau \\ + & 1 & \cos 10\tau \end{array}\right\} e' \sin l'$$

It will be noticed that M does not contain any term having the argument l'. After integration,

$$M = \left\{\begin{array}{lrl} & 0.00003\,22820 & \sin \tau \\ + & 2019\,58114 & \sin 2\tau \\ + & 5\,60460 & \sin 3\tau \\ + & 6\,04140 & \sin 4\tau \\ + & 2670 & \sin 5\tau \\ + & 2789 & \sin 6\tau \\ + & 15 & \sin 7\tau \\ + & 15 & \sin 8\tau \end{array}\right\} e' \sin l' + \left\{\begin{array}{lrl} & 0.00004\,13948 & \cos \tau \\ + & 1542\,75047 & \cos 2\tau \\ + & 3\,75361 & \cos 3\tau \\ + & 4\,57478 & \cos 4\tau \\ + & 1788 & \cos 5\tau \\ + & 2105 & \cos 6\tau \\ + & 10 & \cos 7\tau \\ + & 11 & \cos 8\tau \end{array}\right\} e' \cos l'$$

From this we deduce the following

SPECIAL VALUES OF M

τ		
0°	$+0.01555\,25750\, e' \cos l'$	$0\, e' \sin l'$
15	$1345\,00568\, e' \cos l'$	$+0.01019\,87512\, e' \sin l'$
30	$+\ 772\,63606\, e' \cos l'$	$1764\,47242\, e' \sin l'$
45	$-\ 4\,31439\, e' \cos l'$	$2025\,77999\, e' \sin l'$
60	$775\,31651\, e' \cos l'$	$1746\,54944\, e' \sin l'$
75	$1335\,33942\, e' \cos l'$	$+\ 1003\,74843\, e' \sin l'$
90	$1538\,19663\, e' \cos l'$	$-\ 2\,34984\, e' \sin l'$
105	$1332\,20811\, e' \cos l'$	$1005\,42422\, e' \sin l'$
120	$771\,96674\, e' \cos l'$	$1741\,00398\, e' \sin l'$
135	$-\ 4\,83494\, e' \cos l'$	$2013\,32650\, e' \sin l'$
150	$+\ 765\,49740\, e' \cos l'$	$1747\,00847\, e' \sin l'$
165	$1331\,69118\, e' \cos l'$	$-\ 1010\,22609\, e' \sin l'$
180	$+\ 1539\,43534\, e' \cos l'$	$0\, e' \sin l'$

In the next place are obtained the following

SPECIAL VALUES OF W

τ		
0°	$+0.07206\,87725\,1\, e' \cos l'$	$0\, e' \sin l'$
15	$6373\,32334\,1\, e' \cos l'$	$+0.04138\,52211\,3\, e' \sin l'$
30	$4088\,83403\,1\, e' \cos l'$	$7183\,46977\,7\, e' \sin l'$
45	$+\ 950\,87713\,2\, e' \cos l'$	$8317\,24605\,4\, e' \sin l'$
60	$-\ 2206\,67047\,7\, e' \cos l'$	$7219\,14643\,7\, e' \sin l'$
75	$4527\,76228\,5\, e' \cos l'$	$+\ 4166\,67510\,0\, e' \sin l'$
90	$5372\,55207\,6\, e' \cos l'$	$-\ 16\,50666\,6\, e' \sin l'$
105	$4509\,37054\,1\, e' \cos l'$	$4183\,13967\,5\, e' \sin l'$
120	$-\ 2185\,72203\,8\, e' \cos l'$	$7196\,39977\,7\, e' \sin l'$
135	$+\ 952\,71800\,7\, e' \cos l'$	$8257\,34027\,0\, e' \sin l'$
150	$4057\,57123\,0\, e' \cos l'$	$7111\,96683\,0\, e' \sin l'$
165	$6311\,42691\,8\, e' \cos l'$	$-\ 4090\,85272\,9\, e' \sin l'$
180	$+\ 7132\,62653\,6\, e' \cos l'$	$0\, e' \sin l'$

From these special values we derive the following development of W in periodic series:

$$W = \left\{\begin{array}{lrl lrl} + & 0.00925\,20209\,4 & e' \cos l' & & & \\ + & 15\,41991\,7 & e' \cos (l' - \tau) & + & 0.00002\,48859\,0 & e' \cos (l' + \tau) \\ + & 7279\,31393\,7 & e' \cos (l' - 2\tau) & - & 1008\,74636\,6 & e' \cos (l' + 2\tau) \\ + & 24\,29723\,0 & e' \cos (l' - 3\tau) & - & 4\,93926\,3 & e' \cos (l' + 3\tau) \\ - & 30\,68123\,3 & e' \cos (l' - 4\tau) & + & 4\,08240\,3 & e' \cos (l' + 4\tau) \\ - & 17058\,8 & e' \cos (l' - 5\tau) & + & 26114\,9 & e' \cos (l' + 5\tau) \\ + & 67579\,0 & e' \cos (l' - 6\tau) & - & 9142\,5 & e' \cos (l' + 6\tau) \\ + & 404\,1 & e' \cos (l' - 7\tau) & - & 68\,2 & e' \cos (l' + 7\tau) \\ - & 386\,6 & e' \cos (l' - 8\tau) & + & 51\,0 & e' \cos (l' + 8\tau) \\ - & 3\,9 & e' \cos (l' - 9\tau) & + & 6 & e' \cos (l' + 9\tau) \\ + & 6\,2 & e' \cos (l' - 10\tau) & - & 1\,3 & e' \cos (l' + 10\tau) \end{array}\right\}$$

By the integration of the differential equation which determines w we have the following expression:

$$
\mathrm{w} = \left\{
\begin{array}{lrl lrl}
+ & 0.00674\;50610\;2 & e'\cos l' & & & \\
+ & 2\;39399\;9 & e'\cos(l'-\tau) & - & 0.00252\;38205\;5 & e'\cos(l'+\tau) \\
- & 2899\;18882\;6 & e'\cos(l'-2\tau) & + & 305\;65254\;1 & e'\cos(l'+2\tau) \\
- & 3\;32273\;3 & e'\cos(l'-3\tau) & + & 2\;30508\;2 & e'\cos(l'+3\tau) \\
+ & 13\;82463\;3 & e'\cos(l'-4\tau) & - & 1\;36791\;6 & e'\cos(l'+4\tau) \\
+ & 3513\;1 & e'\cos(l'-5\tau) & - & 1215\;0 & e'\cos(l'+5\tau) \\
- & 7615\;3 & e'\cos(l'-6\tau) & + & 779\;6 & e'\cos(l'+6\tau) \\
- & 33\;4 & e'\cos(l'-7\tau) & + & 11\;0 & e'\cos(l'+7\tau) \\
+ & 65\;2 & e'\cos(l'-8\tau) & - & 6\;6 & e'\cos(l'+8\tau) \\
+ & 3 & e'\cos(l'-9\tau) & - & 1 & e'\cos(l'+9\tau) \\
- & 4 & e'\cos(l'-10\tau) & + & 1 & e'\cos(l'+10\tau)
\end{array}
\right\}
$$

From this are derived the following

SPECIAL VALUES OF w.

τ				
0°	−	0.02157 58418 7 $e'\cos l'$		0 $e'\sin l'$
15		1807 47900 1 $e'\cos l'$	−	0.01527 35055 8 $e'\sin l'$
30	−	844 90341 0 $e'\cos l'$		2640 55345 2 $e'\sin l'$
45	+	486 01318 6 $e'\cos l'$		3028 64411 3 $e'\sin l'$
60		1841 03223 7 $e'\cos l'$		2568 06398 4 $e'\sin l'$
75		2862 85315 8 $e'\cos l'$	−	1365 61467 1 $e'\sin l'$
90		3280 56804 9 $e'\cos l'$	+	260 41159 9 $e'\sin l'$
105		2990 75178 6 $e'\cos l'$		1865 71010 9 $e'\sin l'$
120		2088 92223 8 $e'\cos l'$		3009 19711 1 $e'\sin l'$
135	+	838 08675 4 $e'\cos l'$		3380 87043 2 $e'\sin l'$
150	−	411 91126 3 $e'\cos l'$		2884 08159 3 $e'\sin l'$
165		1323 18927 0 $e'\cos l'$	+	1651 34320 0 $e'\sin l'$
180	−	1655 69829 2 $e'\cos l'$		0 $e'\sin l'$

From the data previously obtained we get the following

SPECIAL VALUES OF $\frac{d\rho}{d\tau}$.

τ				
0°	+	0.06091 01912 9 $e'\cos l'$		0 $e'\sin l'$
15		5158 78573 3 $e'\cos l'$	+	0.01244 94386 6 $e'\sin l'$
30	+	2573 26074 0 $e'\cos l'$		7395 94234 9 $e'\sin l'$
45	−	1055 74291 8 $e'\cos l'$		8582 53152 6 $e'\sin l'$
60		4812 57284 5 $e'\cos l'$		7388 50262 6 $e'\sin l'$
75		7677 79441 1 $e'\cos l'$	+	4038 47342 0 $e'\sin l'$
90		8832 37137 3 $e'\cos l'$	−	577 90963 9 $e'\sin l'$
105		7955 32897 2 $e'\cos l'$		5111 45591 3 $e'\sin l'$
120		5350 01353 2 $e'\cos l'$		8345 26567 4 $e'\sin l'$
135	−	1817 73486 6 $e'\cos l'$		9329 38253 0 $e'\sin l'$
150	+	1638 36514 7 $e'\cos l'$		7900 93575 2 $e'\sin l'$
165		4115 17345 9 $e'\cos l'$	−	4497 95751 8 $e'\sin l'$
180	+	5010 36052 9 $e'\cos l'$		0 $e'\sin l'$

Applying to these values the operation of mechanical quadratures we get

$$
\frac{d\rho}{d\tau} = \left\{
\begin{array}{lrl}
- & 0.01538\;77367\;0 & \\
+ & 539\;56432\;0 & \cos\tau \\
+ & 7190\;05560\;1 & \cos 2\tau \\
+ & 96295\;1 & \cos 3\tau \\
- & 102\;05093\;8 & \cos 4\tau \\
- & 20314\;4 & \cos 5\tau \\
+ & 1\;47482\;3 & \cos 6\tau \\
+ & 524\;7 & \cos 7\tau \\
- & 1616\;2 & \cos 8\tau \\
- & 8\;0 & \cos 9\tau \\
+ & 17\;6 & \cos 10\tau
\end{array}
\right\} e'\cos l' + \left\{
\begin{array}{lrl}
- & 0.00552\;99581\;4 & \sin\tau \\
+ & 8957\;77624\;9 & \sin 2\tau \\
+ & 24\;30526\;0 & \sin 3\tau \\
- & 126\;13921\;9 & \sin 4\tau \\
- & 59785\;4 & \sin 5\tau \\
+ & 1\;81944\;3 & \sin 6\tau \\
+ & 1055\;8 & \sin 7\tau \\
- & 1988\;2 & \sin 8\tau \\
- & 15\;2 & \sin 9\tau \\
+ & 22\;2 & \sin 10\tau
\end{array}
\right\} e'\sin l'
$$

By integration there results

$$
\rho = \left\{
\begin{array}{lrl}
- & 0.19032\;70207\;1 & \\
+ & 512\;72406\;0 & \cos\tau \\
- & 4631\;78417\;9 & \cos 2\tau \\
- & 8\;11629\;9 & \cos 3\tau \\
+ & 32\;06357\;3 & \cos 4\tau \\
+ & 12025\;9 & \cos 5\tau \\
- & 30660\;8 & \cos 6\tau \\
- & 151\;7 & \cos 7\tau \\
+ & 250\;6 & \cos 8\tau \\
+ & 1\;7 & \cos 9\tau \\
- & 2\;2 & \cos 10\tau
\end{array}
\right\} e'\sin l' + \left\{
\begin{array}{lrl}
+ & 0.00498\;11112\;6 & \sin\tau \\
+ & 3782\;26520\;7 & \sin 2\tau \\
+ & 53971\;5 & \sin 3\tau \\
- & 26\;16081\;1 & \sin 4\tau \\
- & 4257\;3 & \sin 5\tau \\
+ & 24993\;5 & \sin 6\tau \\
+ & 76\;7 & \sin 7\tau \\
- & 204\;6 & \sin 8\tau \\
- & 9 & \sin 9\tau \\
+ & 1\;8 & \sin 10\tau
\end{array}
\right\} e'\cos l'
$$

Hence are derived the following

Special Values of ρ

τ			τ		
0°	$-0.23128\,00028\,1\ e'\sin l'$	$0\ e'\cos l'$	105°	$15143\,98827\,2\ e'\sin l'$	$-\ 1433\,29429\,4\ e'\cos l'$
15	$\cdot 22538\,36845\,4\ e'\sin l'$	$+0.01997\,98674\,4\ e'\cos l'$	120	$16997\,68730\,1\ e'\sin l'$	$2866\,77746\,9\ e'\cos l'$
30	$20920\,39137\,4\ e'\sin l'$	$3502\,15719\,9\ e'\cos l'$	135	$19432\,96679\,0\ e'\sin l'$	$3429\,38634\,3\ e'\cos l'$
45	$18696\,55948\,6\ e'\sin l'$	$4134\,64423\,7\ e'\cos l'$	150	$21808\,24983\,0\ e'\sin l'$	$3003\,30996\,5\ e'\cos l'$
60	$16468\,61193\,5\ e'\sin l'$	$3729\,60631\,5\ e'\cos l'$	165	$23517\,46011\,4\ e'\sin l'$	$-\ 1739\,46295\,6\ e'\cos l'$
75	$14866\,86931\,2\ e'\sin l'$	$2394\,78619\,4\ e'\cos l'$	180	$-0.24137\,45332\,1\ e'\sin l'$	$0\ e'\cos l'$
90	$14368\,54518\,3\ e'\sin l'$	$+\ 497\,52806\,2\ e'\cos l'$			

Having now the special values of ρ and w we get the special values of $\delta\lambda$ and $\delta\left(\frac{a}{r}\right)$ by the formulas

$$\delta\lambda = \frac{d\phi}{d\tau}\rho - \frac{d\psi}{d\tau}\frac{\mathrm{w}}{\sqrt{V}}$$

$$\delta\left(\frac{a}{r}\right) = -\frac{a}{r}\left[\frac{d\psi}{d\tau}\rho + \frac{d\phi}{d\tau}\frac{\mathrm{w}}{\sqrt{V}}\right]$$

Thus far we have kept e' indeterminate, but now it is judged advisable to attribute to it the value 0.01677106, which is the same as that used by Delaunay. Moreover, the coefficients of $\delta\lambda$ are transformed into arc.

Special Values.

τ	$\delta\lambda$		$\delta\frac{a}{r}$	
°	″	″	[11]	
0	$-816.05984\,4\ \sin l'$	$0\ \cos l'$	$+36\,75568\,5\ \cos l'$	$0\ \sin l'$
15	$792.69006\,7\ \sin l'$	$+\ 70.75146\,7\ \cos l'$	$30\,48711\,6\ \cos l'$	$+28\,71933\,1\ \sin l'$
30	$729.51228\,3\ \sin l'$	$122.68357\,8\ \cos l'$	$+13\,55645\,2\ \cos l'$	$49\,03195\,6\ \sin l'$
45	$644.88729\,3\ \sin l'$	$142.70351\,7\ \cos l'$	$-\ 9\,14362\,9\ \cos l'$	$55\,29927\,7\ \sin l'$
60	$562.56978\,3\ \sin l'$	$126.87367\,1\ \cos l'$	$31\,45083\,3\ \cos l'$	$46\,14576\,9\ \sin l'$
75	$504.82460\,4\ \sin l'$	$80.69018\,6\ \cos l'$	$47\,76870\,9\ \cos l'$	$+24\,33929\,0\ \sin l'$
90	$486.97775\,1\ \sin l'$	$+\ 16.89635\,2\ \cos l'$	$54\,33233\,6\ \cos l'$	$-\ 4\,38397\,9\ \sin l'$
105	$514.25781\,6\ \sin l'$	$-\ 47.94719\,4\ \cos l'$	$49\,81041\,3\ \cos l'$	$32\,82054\,8\ \sin l'$
120	$580.81136\,9\ \sin l'$	$97.26512\,1\ \cos l'$	$35\,45410\,3\ \cos l'$	$53\,77915\,8\ \sin l'$
135	$670.71818\,9\ \sin l'$	$118.24174\,1\ \cos l'$	$-14\,92205\,9\ \cos l'$	$61\,56411\,8\ \sin l'$
150	$761.18733\,6\ \sin l'$	$105.17933\,6\ \cos l'$	$+\ 6\,33176\,0\ \cos l'$	$53\,48420\,2\ \sin l'$
165	$828.01911\,1\ \sin l'$	$-\ 61.61056\,1\ \cos l'$	$22\,30531\,6\ \cos l'$	$-31\,03229\,5\ \sin l'$
180	$-852.67727\,6\ \sin l'$	$0\ \cos l'$	$+28\,23767\,1\ \cos l'$	$\cdot 0\ \sin l'$

By the application of mechanical quadratures we get the following series. Delaunay's values of the coefficients are added for the sake of comparison in the case of the longitude; in the case of the radius, Delaunay having stopped with terms of the fifth order, it seems hardly worth while to make comparison. They have been obtained by making in his expressions $e = 0$, $\gamma = 0$, and by substituting for his value of $\frac{a}{a'}$, the value which corresponds to the constant 8″.8 of solar parallax; and the terms which involve the simple power of this factor have been multiplied by $1-2\mu$ in order to take into account the moon's mass; but no inductive terms have been added.

$\delta\lambda =$ ″	Del. Coeff. ″	$\delta\left(\frac{a}{r}\right) =$ [10]
$-\ 0.00009\ \sin(l'-8\tau)$		$+\ 7\ \cos(l'-8\tau)$
$-\ 0.00002\ \sin(l'-7\tau)$		$+\ 1\ \cos(l'-7\tau)$
$-\ 0.01054\ \sin(l'-6\tau)$	$-\ 0.0038$	$+\ 699\ \cos(l'-6\tau)$
$-\ 0.00144\ \sin(l'-5\tau)$	$-\ 0.0014$	$+\ 74\ \cos(l'-5\tau)$
$-\ 1.25517\ \sin(l'-4\tau)$	$-\ 1.1916$	$+\ 65281\ \cos(l'-4\tau)$
$-\ 0.09012\ \sin(l'-3\tau)$	$-\ 0.1160$	$+\ 3124\ \cos(l'-3\tau)$
$-152.08250\ \sin(l'-2\tau)$	-152.1127	$+50\,92412\ \cos(l'-2\tau)$
$+\ 0.59511\ \sin(l'-\tau)$	$+\ 0.5718$	$-\ 11723\ \cos(l'-\tau)$
$-659.23785\ \sin l'$	-659.2305	$-11\,47540\ \cos l'$
$+\ 17.69186\ \sin(l'+\tau)$	$+\ 17.5918$	$+\ 1\,28970\ \cos(l'+\tau)$
$-\ 21.60085\ \sin(l'+2\tau)$	$-\ 21.6338$	$-\ 7\,51559\ \cos(l'+2\tau)$
$+\ 0.11250\ \sin(l'+3\tau)$	$+\ 0.1045$	$+\ 5400\ \cos(l'+3\tau)$
$-\ 0.18003\ \sin(l'+4\tau)$	$-\ 0.1809$	$-\ 9530\ \cos(l'+4\tau)$
$+\ 0.00082\ \sin(l'+5\tau)$	$+\ 0.0006$	$+\ 53\ \cos(l'+5\tau)$
$-\ 0.00152\ \sin(l'+6\tau)$	$+\ 0.0004$	$-\ 102\ \cos(l'+6\tau)$
$+\ 0.00001\ \sin(l'+7\tau)$		$0\ \cos(l'+7\tau)$
$-\ 0.00001\ \sin(l'+8\tau)$		$-\ 1\ \cos(l'+8\tau)$

If no errors have been committed in these computations, and pains have been taken to detect and eliminate them, the coefficients set down should correspond to the values of the elements employed with an uncertainty of not more than a unit in the last decimal.

POSITION-ANGLES OF THE NORTH POLAR CAP OF *MARS*, 1898–9.

By E. E. BARNARD.

Gr. M.T.			Appt. Diam. P.C.
	h m	°	″
1898 Nov. 14	24 35	360.6 (3)	. .
15	23 50	347.4 (4)	. .
22	23 20	353.7 (4)	. .
24	23 15	351.7 (4)	4.45
29	23 20	354.2 (4)	. .
Dec. 6	22 30	351.4 (3)	. .
10	19 0	352.8 (4)	. .
11	18 50	352.6 (4)	. .
13	21 20	352.8 (4)	. .
1899 Jan. 18	16 10	347.9 (5)	5.59
24	15 0	347.3 (5)	5.03
30	17 0	348.0 (5)	. .
31	17 55	346.2 (4)	5.07
Feb. 7	13 55	345.6 (4)	. .
10	14 15	346.1 (5)	. .
1899 Feb. 11	15 35	346.0 (4)	. .
12	16 20	346.0 (4)	. .
13	14 0	342.7 (4)	. .
20	16 55	344.0 (4)	. .
28	15 5	342.8 (7)	. .
Mar. 13	16 5	345.1 (6)	. .
18	14 45	345.4 (4)	. .
19	14 35	347.5 (4)	. .
30	14 45	353.4 (4)	. .
Apr. 3	15 7	349.0 (4)	. .
4	14 50	348.2 (4)	. .
20	14 0	347.6 (4)	. .

Observations made with the 40-inch refractor, wire being placed perpendicular to limb of *Mars* at polar cap. Observation much of the time difficult from poor seeing.

ELEMENTS AND EPHEMERIS OF COMET *e* 1899 (GIACOBINI),

By Miss A. HOBE, Y. KUNO, S. C. PHIPPS, and R. SPRAGUE.

(Communicated by the Director of Students' Observatory of the University of California.)

From the first three Mount Hamilton observations by Perrine, kindly telegraphed to the Students' Observatory by Director Keeler, Miss Hobe and Messrs. Kuno and Phipps, advanced students in the University, have computed the following elements and ephemeris of Comet *e* 1899 (Giacobini).

Observations.

Gr. M.T. 1899	α	δ
	h m s	° ′ ″
October 2.6758	16 32 59.7	−4 12 18
3.6378	16 34 22.1	−3 53 35
4.6292	16 35 46.7	−3 34 40

Elements by Miss Hobe, and Messrs. Kuno and Phipps.

$T = $ 1899 July 25.31196 Gr. M.T.

$$\left.\begin{aligned} i &= 90^\circ\ 49'\ 58'' \\ \Omega &= 279\ 54\ 49 \\ {}^*\omega &= 327\ 26\ 20 \end{aligned}\right\}\ 1899.0$$

$$\log q = 0.128376$$

$$(O-C)\quad \Delta\lambda\cos\beta = -1''.5\ ,\quad \Delta\beta = -0''.1$$

* In the telegram sent to Harvard College Observatory ω was 10′ too small.

Constants for the Equator of 1899.0.

$$x = [9.365813]\ (62^\circ\ 11'\ 36''+v)\ \sec^2\tfrac{1}{2}v$$
$$y = [0.123290]\ (213\ 33\ \ 3+v)\ \sec^2\tfrac{1}{2}v$$
$$z = [0.126916]\ (304\ 16\ 30+v)\ \sec^2\tfrac{1}{2}v$$

Ephemeris for Greenwich Midnight.

1899	α	δ	log Δ	Br.
	h m s	° ′ ″		
October 8.5	16 41 13.9	−2 24 8	0.3175	0.84
12.5	46 45.2	−1 16 5	0.3340	
16.5	52 11.9	−0 12 5	0.3495	
20.5	57 34.7	+0 48 34	0.3640	0.60

Brightness Oct. 2 is taken as unity.

Mr. Roger Sprague has independently computed the orbit from the same observations corrected for parallax and aberration on the basis of a first approximation.

Elements by Roger Sprague.

$T = $ 1899 July 25.5208

$$\left.\begin{aligned} i &= 90^\circ\ 38'\ 22'' \\ \Omega &= 279\ 47\ \ 0 \\ \omega &= 327\ 53\ 50 \end{aligned}\right\}\ 1899.0$$

$$\log q = 0.130868$$

$$(O-C)\quad \Delta\lambda\cos\beta = -0''.8\ ,\quad \Delta\beta = +0''.3$$

CONTENTS.

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MICROMETRICAL MEASURES OF THE FIFTH SATELLITE OF *JUPITER* AND ON THE MOTION OF THE LINE OF APSIDES OF THE ORBIT OF THE SATELLITE,

BY E. E. BARNARD.

MADE WITH THE 40-INCH REFRACTOR OF THE YERKES OBSERVATORY.

The Fifth Satellite of *Jupiter* was measured with the 40-inch at the oppositions of 1898 and 1899.

The increasing southerly declination of *Jupiter* and the bad season in which the oppositions now occur, make the satellite a difficult object. It has been fairly well seen, however, on several dates, and good measures secured of it.

The steadiness of the great telescope and the clock-work and the protection offered by the curtain wind-break, have made it possible to measure the satellite with considerable exactness when it could be seen at all, though in some of the measures it was at the limit of vision.

It has always appeared to me when measuring this object, from the fact that the orbit is not only eccentric, but that the line of apsides is in rapid motion, that it would be best to make as many measures, and as continuous a set as possible, so as to cover a large part of the orbit. For this reason I have on several occasions held on to it and measured it as rapidly and for as long a time as possible.

TISSERAND has shown that the eccentricity of the orbit, though very small, is clearly indicated in the measures with the 36-inch in 1892 and 1893. He showed that from the great polar compression of *Jupiter* the line of apsides of the orbit of this satellite should have a motion of about +882° a year, or +2°.42 daily, which would give a complete revolution in five months. From the Lick measures of elongation distances in 1892 and 1893, he found the semi-major axis of the orbit to be 47″.906, the eccentricity 0.0073, and the longitude of the perijove for 1892 Nov. 1 = −4°.

To test the motion of the line of apsides TISSERAND made a series of comparisons of the measured elongation distances with calculation, on three assumptions. These were R_0 that the orbit was a circle, R_1 that it was an ellipse with the above eccentricity and with the perijove stationary; R that the perijove had a positive motion of 2°.42 a day.

The results of these comparisons with five normal places are as follows, taken in the order Observed minus Calculation.

R_0	R_1	R	
″	″	″	
+0.17	+0.02	+0.02	
+0.20	+0.04	−0.11	$\Sigma R_0^2 = 0.166$
+0.25	+0.06	+0.12	
+0.06	−0.14	+0.08	$\Sigma R_1^2 = 0.235$
−0.27	−0.14	−0.13	
−0.20	−0.11	+0.11	$\Sigma R^2 = 0.087$
+0.18	+0.24	+0.10	
−0.43	−0.24	−0.09	
+0.03	+0.25	−0.08	

"From which it is seen that the representation of the residuals R is much more satisfactory than those of R_1 and R_0." (*Comptes Rendus* No. 15 for 1894 October 8, Tome CXIX).

It would appear, therefore, that for the exact determination of the eccentricity and the rate of revolution of the perijove, as many measures of the satellite in all parts of its orbit should be secured as possible, and especially important are careful determinations of the elongation distances.

As soon as a proper distribution of elongation distances is secured, I hope to repeat TISSERAND's calculations.

The motion of the line of apsides ought now to be determined accurately from the observations alone.

Six measures of the elongation distances of the satellite have been secured here at the oppositions of 1898 and 1899. Though these clearly show the eccentricity they do not sufficiently cover the orbit for a good re-determination of the quantities desired.

In the meantime, it is possible to form some idea of the soundness of TISSERAND's theory by a comparison of observations with the theory. It will be seen that his value for

the motion of the perijove represented the observations used by him very closely. If one uses this motion for the prediction of the satellite's position at the present time, it will be found that the observations are not well represented; indeed, this year (1899), while the measures clearly showed the perijove was preceding the planet, theory should have made it following. This being the case, it is evident that the value determined by TISSERAND is not the correct one. An approximation to the true value can be obtained by a comparison of the observations with an assumed value, which can be varied until a proper adjustment is had. It appears that a somewhat larger motion will best satisfy the measures, the best results being got with a daily motion of $+2^\circ.465$ or $+900^\circ$ a year, or a complete revolution of the orbit in 4.9 months.

With this value and TISSERAND's determinations of the eccentricity and major axis of the orbit, I have calculated the elongation distances for the dates of my measures at elongation.

The following residuals result (Observation minus Calculation):

	Obs'd	Comp.	Resid. (O—C)
	"	"	"
1892 Sept. 12	48.11 (4) E	48.08	+0.03
Oct. 8	48.14 (4) E	48.25	−0.11
19	47.51 (4) W	47.62	−0.11
26	48.19 (3) E	48.12	+0.07
Nov. 10	47.98 (3) E	47.91	+0.08
11	47.97 (3) W	47.92	+0.05
1893 Sept. 27	47.67 (3) E	47.74	−0.07
Nov. 12	47.74 (2) E	47.71	+0.03
Dec. 10	48.12 (1) E	48.12	0.00
1894 Dec. 3	48.17 (1) E	48.02	+0.15
1898 Mar. 15	48.12 (3) E	48.13	−0.01
1899 May 6	48.31 (3) E	48.21	+0.10
June 16	48.03 (1) E	47.99	+0.04

E and W are the east and west elongations. The figures in parentheses represent the number of observations used.

The new value of the motion of the line of apsides represents the observations used by TISSERAND even better than the theoretical value, as it reduces the sum of the squares of the residuals to nearly one-half, from 0.087 to 0.045.

I do not know what value of the compression of *Jupiter* TISSERAND used, but assume he has taken the most probable one. Since the motion of the perijove is greater than the observed compression would produce, we are led to the conclusion that there must be a greater distribution of matter at the equator of the planet than a uniform density would suggest. This is an interesting question, and one that can easily be settled by observations of this satellite, though it would appear that the other four satellites are not suitable for such an investigation.

From the preceding comparisons of the measured with the computed elongation distances, it would seem that a determination of the position of the satellite at elongation with either the 36-inch or the 40-inch can be depended on to not far from $\frac{1}{10}$ of a second of arc.

During the present measures with the great telescope, as in the previous observations of the satellite, one-half the field was covered with a piece of smoked mica. In this way the satellite could be seen in the unobscured portion of the field, while the planet itself was dimmed by the intervening mica.

The distances have been measured from the nearest limb of *Jupiter*, and the corrections to the center of the planet made with my own values of the diameters of *Jupiter*. In this connection, these values of the diameters of *Jupiter* should always be used in my measures of this satellite, otherwise very serious errors may be introduced. It is known, as pointed out in the earlier papers on this subject (*A.J.* 325), that there is a great difference in the diameter measures of *Jupiter* made with different instruments. Especially is this very marked when filar-micrometer and heliometer measures are compared. The heliometer seems to give a smaller diameter to *Jupiter* by upwards of an entire second.

Whatever may be the true diameter of *Jupiter*, and I think filar-micrometer measures are more likely to be true than those obtained with the heliometer, the measures of the satellite should be reduced with the diameters obtained with the same telescope if possible, or one nearly like it. My diameters with the 36-inch should therefore be used in all my measures of this satellite.

These values are (*A.J.* 325).

Polar Diameter $= 36''.112$ (at Δ 5.20)
Equatorial Diameter $= 38.522$ (at Δ 5.20)

As these diameters were measured through smoked mica (*A.J.* 285–86) similar to that used in measuring the satellite, they will be as nearly free from irradiation effects as possible, and whatever irradiation effect may remain, it is neutralized by the fact that the bisected limb in the satellite measures is observed through the smoked mica also.

During the present measures, it was possible on several occasions to carry the satellite through its elongation and to secure both elongation time and distance.

Following are the times of greatest east elongation from the measures last year:

1898 March 2 $12^h\ 57^m.80$
6 12 36.11

During the present opposition of 1899, careful determinations of the elongation times were made on two dates. To show the consistency of the results the individual determinations are given:

1899 Apr. 25 East Elongation	1899 May 1 East Elongation
13ʰ 4ᵐ.99	12ʰ 33ᵐ.25
4.89	32.95
4.99	32.95
5.69	32.55
4.99	32.55
5.69	12 32.25
13 5.59	
13 5.26	12 32.72

These were determined by curves through the plotted individual measures.

The following are the elongation times determined from the measures:

Times of East Elongation in 1898.

	h m
March 2	12 57.80
6	12 36.11

Times of East Elongation in 1899.

	h m
April 25	13 5.26
May 1	12 32.72

I have obtained the following three values of the period of the satellite:

	P	Rev
	h m s	
1892 Sept. 10 to 1898 March 6	11 57 22.652	1020
1892 Sept. 10 to 1899 April 25	11 57 22.637	1853
1892 Sept. 10 to 1899 May 1	11 57 22.653	1865
Mean	11 57 22.647	

This is doubtless correct to the $\frac{1}{100}$ part of a second.

Following are elongation distances obtained by plotting the measures:

East Elongation Distances in 1898.

	″	
March 2	48.10	(Δ5.20)
6	48.14	(Δ5.20)
April 5	48.12	(Δ5.20)

East Elongation Distances in 1899.

	″	
April 25	48.34	(Δ5.20)
May 1	48.29	(Δ5.20)
23	48.31	(Δ5.20)
June 16	48.03	(Δ5.20)

Following are the measures of the satellite obtained with the 40-inch during the last two oppositions:

1898 *March* 2.

90th Merid. Time	Δ from f. limb	Δ from center	Comps.
h m s	″	″	
12 13 24	27.82	49.88	3
12 41 57	32.64	54.70	3
12 48 59	32.64	54.70	3
12 53 38	32.75	54.81	2
13 1 13	32.63	54.69	2
13 15 23	32.05	54.11	2
13 23 19	31.58	53.64	3
13 29 31	30.83	52.89	3
13 39 5	30.09	52.12	3

Apparent semi-equatorial diameter of *Jupiter* = 22″.06.

1898 *March* 6.

90th Merid. Time	Δ from f. limb	Δ from center	Comps.
h m s	″	″	
11 25 29	22.17	44.35	2
11 30 9	24.16	46.34	3
11 39 11	25.99	48.17	3
11 44 16	27.10	49.28	2
11 50 47	28.95	51.13	2
11 56 5	29.03	51.21	2
11 59 23	30.84	53.02	3
12 5 8	31.40	53.58	3
12 7 49	31.69	53.87	2
12 17 22	32.17	54.35	2
12 19 56	32.84	55.02	3
12 23 31	33.27	55.45	3
12 29 18	33.12	55.30	3
12 33 31	33.39	55.57	2
12 37 25	32.95	55.13	3
12 42 26	33.29	55.47	3
12 47 19	32.68	54.86	3
12 51 37	32.60	54.78	3
12 56 28	32.29	54.47	3
13 1 11	31.52	53.70	3

1898 *March* 6.—Cont.

90th Merid. Time	Δ from f. limb	Δ from center	Comps.
h m s	″	″	
13 7 4	31.01	53.19	2
13 12 17	30.53	52.71	3
13 18 58	29.33	51.51	3
13 24 39	28.22	50.40	2
13 30 17	26.68	48.86	3
13 37 14	25.58	47.76	2
13 45 28	23.07	45.25	3
13 51 54	20.22	42.40	3

Apparent semi-equatorial diameter of *Jupiter* = 22″.18.

1898 *April* 5.

90th Merid. Time	Δ from f. limb	Δ from center	Comps.
9 18 7	31.87	54.24	3
9 21 40	31.99	54.36	3
9 25 57	33.09	55.46	2
9 31 15	32.81	55.18	2
9 35 59	33.57	55.94	3
9 38 27	33.11	55.48	2
9 40 34	33.53	55.90	2
9 50 34	33.20	55.57	3
9 53 44	33.22	55.59	3
9 56 30	33.94	56.31	3
9 59 4	33.15	55.52	3
10 1 4	33.18	55.55	2
10 4 14	33.28	55.65	3
10 7 7	33.00	55.37	3
10 9 54	32.36	54.73	3
10 13 27	33.17	55.54	3
10 16 11	32.42	54.79	2
10 19 25	31.66	54.03	3
10 22 55	31.39	53.76	3
10 26 15	30.98	53.35	3
10 28 54	30.89	53.26	2

1898 *April* 5.—Cont.

90th Merid. Time	Δ from f. limb	Δ from center	Comps.
h m s	″	″	
10 32 17	30.46	52.83	3
10 34 12	30.01	52.38	2
10 39 44	28.52	50.89	3
10 41 57	27.15	49.52	2
10 47 24	27.22	49.59	2
10 50 9	25.86	48.23	3
10 54 12	24.70	47.07	3
10 58 57	24.05	46.42	3

Apparent semi-equatorial diam. = 22″.39.
Correction for phase = −0″.02.

1898 *April* 20.

90th Merid. Time	Δ from f. limb	Δ from center	Comps.
8 48 14	32.25	54.16	3
8 51 26	31.82	53.73	3
8 55 49	31.22	53.13	3
8 59 47	30.68	52.59	3
9 3 9	30.86	52.77	3
9 6 2	30.62	52.53	2
9 8 52	29.65	51.56	3
9 12 7	29.26	51.17	3
9 15 49	28.17	50.08	3
9 18 50	27.97	49.88	3
9 21 55	27.34	49.25	3
9 25 1	26.66	48.57	3
9 28 20	25.99	47.90	3
9 32 0	24.96	46.87	2
9 36 55	23.53	45.44	3
9 40 16	23.11	45.02	3
9 42 52	22.10	44.01	3
9 44 57	21.94	43.82	2
9 46 39	21.13	43.04	2

Apparent semi-equatorial diam. = 22″.00.
Correction for phase = −0″.08.

1898 *April* 26.

90th Merid. Time h m s	Δ from f. limb ″	Δ from center ″	Comps.
7 35 19	31.63	53.30	3
7 39 15	31.94	53.61	3
7 42 49	32.21	53.88	3
7 46 41	31.96	53.63	2
8 3 14	32.29	53.96	3
8 6 15	32.25	53.92	3
8 9 32	32.52	54.19	3
8 13 16	31.63	53.30	3
8 16 7	31.88	53.55	3
8 18 30	31.44	53.11	3
8 23 13	31.00	52.67	3
8 28 9	30.41	52.08	3
8 32 22	30.35	52.02	3
8 36 0	29.99	51.66	3
8 43 30	28.01	49.68	2
8 49 48	26.63	48.30	3
8 52 35	26.33	47.88	2
8 55 24	25.92	47.47	2
8 59 7	24.59	46.14	3

Apparent semi-equatorial diam. = 21″.79.
Correction for phase = — 0″.12.

From South Limb.

7 50 14	20.31	−0.12	
7 51 45	19.90	−0.53	
7 52 30	20.58	+0.15	
7 53 20	19.89	−0.54	
7 54 35	20.08	−0.35	
7 52 29		−0.28	

From North Limb.

7 56 10	20.89	−0.46	
7 56 36	20.82	−0.39	
7 57 45	20.80	−0.37	
7 59 55	20.44	−0.01	
8 0 32	20.21	+0.21	
7 58 11		−0.20	

Apparent semi-polar diameter = 20″.43.
Position-angle of wires at latitude measures = 115°.2.

1899 *April* 18.

13 57 40	32.19	54.77	2
14 1 35	32.17	54.74	
14 3 25	32.24	54.82	
14 7 35	32.49	55.06	
14 8 30	31.72	54.29	
14 10 17	31.39	53.97	
14 11 45	31.95	54.53	
14 14 40	31.64	54.22	
14 17 3	31.20	53.77	
14 19 12	31.04	53.62	
14 21 5	31.31	53.88	
14 22 15	31.13	53.71	

Apparent semi-equatorial diam. = 22″.58.
Correction for phase = — 0″.01.
(This has not been applied.)

1899 *April* 20.

90th Merid. Time h m s	Δ from f. limb ″	Δ from center ″	Comps.
12 56 36	31.42	54.02	2
12 58 21	31.17	53.77	2
13 2 30	31.79	54.39	2
13 5 3	32.16	54.76	2
13 7 5	32.00	54.60	2

Apparent semi-equatorial diam. = 22″.60.
Correction for phase = 0″.00.

From South Limb.

13 11 33	20.91	−0.27	1
13 12 53	20.15	−1.04	1
13 13 41	21.36	+0.18	1
13 15 48	21.90	+0.71	1
13 16 34	21.63	+0.44	1
13 14 58		0.00	

From North Limb.

13 17 33	22.01	−0.83	
13 19 8	21.26	−0.08	
13 19 53	20.38	+0.80	
13 20 43	20.85	+0.33	
13 21 23	20.63	+0.55	
13 22 38	20.76	+0.43	
13 20 13		+0.20	

From South Limb.

13 23 58	23.57	+2.39*	1
13 24 43	22.54	+1.36	1
13 25 53	21.95	+0.76	1
13 26 48	21.68	+0.49	1
13 27 22	22.68	+1.50	1
13 26 12		+1.03	

* Reject.

From North Limb.

13 28 35	20.45	+0.74	1
13 30 3	20.03	+1.15	1
13 31 0	20.86	+0.32	1
13 29 53		+0.74	

Apparent semi-polar diameter = 21″.18.
P.-A. of wires for lat. measures = 111°.0.

From Following Limb.

13 34 56	34.13	56.73	3
13 38 36	34.00	56.60	2

1899 *April* 25.

12 1 48	25.20	47.82	3
12 1 29	26.10	48.72	3
12 7 26	26.57	49.19	3
12 9 45	27.49	50.11	2
12 11 31	27.97	50.59	2
12 13 49	28.29	50.91	3
12 17 26	28.98	51.60	3
12 21 14	29.55	52.17	3
12 25 12	30.56	53.18	3
12 29 28	30.96	53.58	3
12 31 55	31.29	53.91	2
12 34 36	31.82	54.44	2

1899 *April* 25. — Cont.

90th Merid. Time h m s	Δ from f. limb ″	Δ from center ″	Comps.
12 38 18	32.17	54.79	3
12 40 55	32.70	55.32	3
12 44 43	33.02	55.64	3
12 48 13	33.77	56.39	3
12 50 45	33.53	56.15	3
12 51 47	33.88	56.50	3

From South Limb.

13 1 9	21.82	+0.61	1
13 2 19	22.18	+0.97	1
13 3 19	22.33	+1.13	1
13 4 9	22.93	+1.73	1
13 2 44		+1.11	

From North Limb.

13 5 36	20.69	+0.52	1
13 6 29	19.99	+1.21	1
13 7 24	20.50	+0.71	1
13 8 4	20.75	+0.45	1
13 8 51	19.81	+1.40	1
13 9 59	19.91	+1.30	1
13 7 44		+0.96	

Apparent semi-polar diameter = 21″.21.
P.-A. of wires at lat. measures = 111°.2.

13 14 14	33.53	56.15	2
13 17 31	33.91	56.53	3
13 22 15	33.22	55.84	3
13 25 7	33.58	56.20	3
13 28 56	32.91	55.53	3
13 32 13	32.37	54.99	2
13 38 42	31.47	54.09	3
13 42 23	31.10	53.72	3
13 45 7	30.81	53.43	3
13 50 7	29.25	51.87	3
13 54 7	29.05	51.67	3
13 56 33	28.63	51.25	3
13 58 49	27.79	50.41	3
14 1 15	27.13	49.75	3
14 4 12	26.38	49.00	3
14 10 29	25.28	47.90	3
14 11 55	25.12	47.74	3
14 14 41	24.12	46.70	3
14 20 24	22.36	44.98	3
14 23 45	21.64	44.26	3
14 27 4	20.51	43.13	3
14 31 18	19.36	41.98	3

Apparent semi-equatorial diam. = 22″.62.

1899 *May* 1.

11 10 49	19.79	43.38	3
11 15 17	21.31	43.91	3
11 19 9	22.18	44.77	3
11 22 44	23.49	46.08	3
11 32 56	26.19	48.79	3
11 36 19	26.88	49.47	3
11 38 16	27.89	50.49	2
11 45 34	28.92	51.52	3
11 48 48	29.87	52.47	2
11 52 48	30.53	53.13	3

1899 *May* 1. — Cont.

90th Merid. Time h m s	Δ from f. limb ″	Δ from center ″	Comps.
11 56 16	30.86	53.46	3
11 59 15	31.61	54.21	3
12 3 29	31.97	54.57	2
12 6 50	32.59	55.19	3
12 10 21	32.70	55.29	3
12 12 12	33.44	56.04	1
12 14 17	78.58	55.98	3*
12 16 33	33.43	56.04	3
12 19 12	33.59	56.19	3
12 20 41	33.58	56.18	2
12 25 25	33.99	56.59	3
12 28 31	33.80	56.40	3
12 31 6	34.25	56.85	2
12 32 34	34.19	56.79	2
12 35 2	33.93	56.53	3
12 38 14	34.01	56.61	3
12 41 56	33.80	56.40	3
12 44 57	33.52	56.12	3
12 49 3	33.72	56.32	3
12 52 46	33.22	55.82	3
12 56 21	32.61	55.21	3
13 0 13	32.34	54.91	3
13 2 4	32.04	54.64	2
13 5 9	31.45	54.05	3
13 8 44	31.19	53.79	3
13 10 55	30.53	53.12	2
13 13 48	30.61	53.21	2
13 16 36	29.70	52.30	3
13 18 55	29.47	52.07	2
13 24 36	27.95	50.55	3
13 27 39	27.49	50.09	3
13 32 38	26.38	48.97	3
13 36 14	25.34	47.94	3
13 39 53	24.49	47.09	3
13 43 31	23.14	45.73	3
13 49 13	22.37	44.96	3
13 51 26	20.39	42.99	2

Apparent semi-equatorial diam. = 22″.60.

* From preceding limb.

1899 *May* 23.

90th Merid. Time h m s	Δ from f. limb ″	Δ from center ″	Comps.
9 28 18	23.98	45.97	2
9 32 43	25.42	47.41	2
9 36 58	25.62	47.61	2
9 46 23	28.83	50.82	3
9 51 6	29.39	51.38	2
9 55 48	29.58	51.57	3
10 0 37	30.80	52.79	2
10 3 42	31.57	53.56	3
10 6 19	31.52	53.51	3
10 9 49	31.81	53.79	3
10 12 26	31.97	53.96	2
10 14 4	32.71	54.70	2
10 16 33	32.40	54.39	3
10 19 12	32.70	54.69	3
10 22 12	32.89	54.88	3
10 26 49	33.67	55.66	3
10 29 0	33.49	55.48	3
10 33 38	33.21	55.20	3
10 37 18	33.11	55.10	3
10 41 40	32.57	54.56	3
10 45 30	32.97	54.96	3
10 48 30	33.17	55.16	3
10 51 10	32.24	54.23	3
10 55 2	43.76	54.75	3
10 58 15	32.21	54.20	2
11 1 32	31.56	53.55	3

Apparent semi-equatorial diam. = 22″.08.
Correction for phase = — 0″.09.

1899 *June* 13.

9 1 5	31.06	51.82	3
9 7 57	30.83	51.60	3
9 10 29	30.53	51.30	3
9 13 13	30.46	51.23	3
9 16 43	29.86	50.63	2
9 19 8	28.91	49.67	2
9 22 51	28.62	49.39	3
9 28 17	27.10	47.87	3
9 31 12	27.11	48.18	3

Apparent semi-equatorial diam. = 21″.00.
Correction for phase = — 0″.23.

1899 *June* 16.

90th Merid. Time h m s	Δ from f. limb ″	Δ from center	Comps.
8 23 29	31.41	52.12	3
8 27 17	31.63	52.32	3
8 30 20	31.34	52.05	3
8 32 50	31.49	52.20	3
8 36 00	31.78	52.49	3
8 38 48	31.44	52.15	3
8 42 22	31.01	51.71	3
8 45 26	31.46	52.17	3
8 48 51	30.36	51.07	3
8 51 43	30.65	51.36	3
8 55 24	30.11	50.81	2
8 58 57	29.19	49.89	3
9 1 11	29.15	49.85	2
9 4 4	28.76	49.46	3
9 8 0	28.41	49.11	3
9 10 54	27.75	48.46	3
9 13 56	27.15	47.86	3
9 18 31	26.14	46.85	3

Apparent semi-equatorial diam = 20″.95.
Correction for phase = — 0″.24.

1899 *June* 18.

9 0 2	27.28	47.86	3
9 4 27	27.18	47.75	2
9 8 36	25.36	45.94	2

Apparent semi-equatorial diam. = 20″.84.
Correction for phase = — 0″.26.

1899 *June* 19.

8 26 7	30.49	51.00	3
8 29 20	30.01	50.52	3
8 31 42	30.48	50.99	2
8 38 29	30.23	50.74	3
8 41 58	29.64	50.15	3
8 45 22	28.54	49.05	2
8 48 37	27.77	48.28	2
8 53 55	27.61	48.12	3
8 58 27	26.97	47.18	3
9 5 26	25.06	45.57	3

Apparent semi-equatorial diam. = 20″.78.
Correction for phase = — 0″.27.

In all the observations made at the Yerkes Observatory, the recorded times are six hours slow of Greenwich.

The apparent semi-diameters of *Jupiter* that I have given here have had the phase correction applied to them before using for reduction of the satellite measures.

During this work, and while looking for the satellite at other times, the position-angles of the belts of *Jupiter* have been measured. In these determinations I have made a greater number of settings than in my previous observations of the belts. In each case they represent the apparent position-angle of the great equatorial belt. The settings were made with considerable care, and the observations are a continuation of my measures previously printed in the *Astronomical Journal* (275, 285–86, 325, 367).

Position-Angles of the Belts of *Jupiter*.

Date (6 hrs. slow of Gr.)		h m	P. A.	Comps.
1897 Dec.	7	18 0	115.8	5
	20	16 5	116.0	5
	26	18 43	115.0	4
	27	18 36	114.5	3
1898 Jan.	6	16 0	114.9	4
	24	15 20	115.5	5
Feb.	26	12 12	116.0	3
Mar.	7	12 20	115.3	5
	15	12 52	115.1	4
	19	11 0	115.6	5
	23	10 50	117.0	4
	28	11 5	116.6	4
Apr.	2	10 40	117.7	5
	14	9 55	116.6	4

Position-Angles. — Cont.

Date (6 hrs. slow of Gr.)			h m	P.-A.	Comps.
1898	May	3	8 10	116.5	5
		9	9 0	115.3	5
		16	7 45	114.6	5
	June	13	8 20	115.5	1
1899	Feb.	1	17 25	112.2	1
		13	16 0	109.4	4
		26	15 22	107.0	1
	Apr.	5	13 0	107.8	4
		18	13 50	107.8	1
		18	14 35	110.2	4
		19	12 50	109.6	4
		25	12 0	111.4	1
	May	1	11 10	109.5	1
		8	19 20	112.5	4
		21	9 15	113.6	1
		22	9 20	113.1	5

In the previous papers in the *Astronomical Journal*, I have given the measures of the satellite in two coordinates, principally in distances perpendicular to the axis of *Jupiter*. A good many measures of distances from the north and south limbs of the planet were also made. It was customary in these latter measures to place the wires parallel with the belts of *Jupiter* for the settings. A slight error in such a setting would affect the measures appreciably, and I should have given the position-angles of the wires for these settings. Such an error would not sensibly affect the longitude measures. A record was kept of the original settings, and as they are important in future investigations of the orbit of this satellite, I have collected these and have converted them into position-angle. They follow:

Position Angles of the Wires in the Latitude-Measures in 1892-93-94.

1892	h m h m	°	1892	h m h m	°	1892		°
Sept. 12	. . . . . .	66.6	Oct. 7	8 53 to 9 3	67.1	Nov. 20	. . . . . .	65.1
13	. . . . . .	67.4		12 3 to 12 9	66.6	1893 Sept. 24	. . . . . .	78.5
14	11 1 to 11 11	67.4	17	. . . . . .	67.0	Nov. 6	. . .	75°.5 or 77.5
	13 17 to 13 48	67.1	21	. . . . . .	66.7	12	. . . . . .	76.9
	14 0 to 14 5	67.0	23	7 29 to 7 34	66.3	13	. . . . . .	76.3
16	. . . . . .	66.8		10 7 to 10 15	66.5	19	. . . . . .	76.6
23	10 8 to 10 29	67.0		13 48 to 13 53	66.0	Dec. 10	. . . . . .	71.9
	12 36 to 12 44	67.1	28	. . . . . .	66.1	1894 Nov. 18	. . . . . .	86.6
27	9 18 to 10 17	66.7	Nov. 4	. . . . . .	66.2			
	12 13 to 12 55	66.3	11	. . . . . .	65.8			

In *A.N.* 3404 Dr. Fritz Cohn has an exhaustive investigation of the orbit of the Fifth Satellite from the observations by Struve, and by myself previous to 1895. I was not in this country when Dr. Cohn's paper appeared, and though I saw it then, I had not noticed the value he had obtained for the motion of the perijove, which seems to have been 911°.7 annually. My attention has but recently been called to it.

This value does not seem to satisfactorily represent the elongation distances which I have given. I have, however, used Tisserand's value for the eccentricity and major axis.

On 1893 Nov. 6, I find that for the longitude measures the position-angle of the wires for the distances was 165°.5, which was found to be 2°.0 in error by a misreading of the circle when setting for the parallel of the belts. This would produce an error of only about 0″.02 in the longitude-measures. If this error also entered into the settings for the latitude-measures, it would be decidedly noticeable. From Dr. Cohn's paper in *A.N.* 3404, I presume the error also entered into the latitude-measures. There is a note to the effect that the position-angle of the wires for these measures on that date was either 77°.5 or 75°.5. This was overlooked when preparing the manuscript for printing. For the latitude-measures this makes a difference of about one second of arc, which will account for the apparently large discrepancy on 1893 Nov. 6.

Yerkes Observatory, Williams Bay, Wis., 1899 Oct. 7.

NOTE ON STARS IN THE GREAT NEBULA IN *ORION*.

By J. ADAIR LYON.

While engaged in work upon the Star-Cluster of the central part of the Great *Orion*-Nebula, with the 26-inch equatorial of the Leander McCormick Observatory, I noticed on the night of September 14, several faint stars which did not appear upon Bond's Chart and Catalogue of this cluster, as published in the *Annals of Harvard Observatory*, Vol. V. Two of these stars, *a* and *b*, as designated below, were undoubtedly glimpsed on the night of 1898 November 22, but were not seen upon any other night during that opposition, though careful search was made. The night of September 14 was exceptionally fine, and these stars were seen without difficulty, one, and probably three more, being

seen in the same field. On Sept. 15, I obtained meaures of $\Delta\alpha$ and $\Delta\delta$ of stars a, b and c, with reference to star 690 of Bond's Catalogue, which measures are here given:

Star	$\Delta\alpha$	$\Delta\delta$	Comp. Star
	s	"	
a	−15.20	−65.90	690
b	−11.87	−61.17	690
c	− 3.00	−36.23	690

Two other stars, d and e, are also suspected, measures of the positions of which I was unable to obtain at that time. These lie roughly about a third of the distance from 598 to 680, and a little preceding the line joining these two stars.

The magnitudes, based upon a comparison with the Bond stars in the same field, are $a = 701 > b = c > d > e$, ranging from $14^M.8$, this being the magnitude assigned by BOND to 701, to $15^M.5$.

I will be very much obliged to any observer having access to large instruments if they will confirm the existence of these stars as above described, or if they will give me any information of a previous observation of them. Star a is probably identical with star 55 in Sir J. HERSCHEL'S catalogue of this cluster, but does not seem to be recorded by BOND. Of the others, I can find no previous record.

Charlottesville, 1899 *Sept.* 19.

ELEMENTS AND EPHEMERIS OF COMET e 1899 (*GIACOBINI*).

By C. D. PERRINE.

The following observations were used as the basis for these elements:

1899 Gr. M.T.	App. α	App. δ	
	h m s	° ′ ″	
Oct. 1 6 38 27	16 31 0.7	−4 39 50	Kön.
7 15 45 20	16 40 8.02	−2 37 49.1	Mt. H.
16 14 45 28	16 53 13.68	+0 1 44.1	Mt. H.

Parallax and aberration corrections were applied, using data from the orbit computed at the Students' Observatory of the University of California by Miss A. HOBE and Messrs. Y. KUNO, S. C. PHIPPS and R. SPRAGUE.

The following elements result:

$$T = 1899 \text{ Sept. } 15.0430 \text{ Greenwich M.T.}$$

$$\left.\begin{aligned} \omega &= 10^\circ\ 51'\ 55''.9 \\ \Omega &= 272\ \ 12\ \ 32.1 \\ i &= 76\ \ 55\ \ 18.8 \end{aligned}\right\} 1899.0$$

$$\log q = 0.251754$$

$$\text{O}-\text{C}: \quad \Delta\lambda' \cos\beta' = +8''.9 \quad , \quad \Delta\beta' = +1''.8$$

Lick Observatory, University of California, 1899 *October* 21.

The character of the orbit is such that any error in the latitude will cause a much larger error in longitude.

CONSTANTS FOR THE EQUATOR OF 1899.0.

$$\begin{aligned} x &= [9.360542]\, r \sin(\ 20^\circ\ 32'\ 21''.4 + v) \\ y &= [9.996607]\, r \sin(258\ \ 22\ \ \ 5.6 + v) \\ z &= [9.991796]\, r \sin(346\ \ 57\ \ 15.4 + v) \end{aligned}$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1899	True α	True δ	log Δ	Br
	h m s	° ′		
Nov. 13.5	17 36 23	+ 7 37.3	0.405	0.57
15.5	39 37	8 9.5		
17.5	42 52	8 41.8	0.410	0.55
19.5	46 8	9 14.3		
21.5	49 25	9 46.8	0.415	0.52
23.5	52 41	10 19.6		
25.5	56 3	10 52.6	0.420	0.50
27.5	17 59 24	11 25.8		
Nov. 29.5	18 2 45	11 59.2	0.424	0.48
Dec. 1.5	6 8	12 32.9		
3.5	18 9 32	+13 6.9	0.429	0.46

The unit of brightness is that on October 1.

PERIODICAL CHANGES IN THE FORM OF THE *GEGENSCHEIN*.

By E. E. BARNARD.

In previous papers on the *Gegenschein*, *A.J.* Vol. VII, No. 168; Vol. XI, No. 243; Vol. XIII, No. 308, and Vol. XVII, No. 403, I have called attention to an important change — among other changes — in the form of the *Gegenschein*, which occurs in the first part of October. In a recent summation of the results of fifteen years' observation of the *Gegenschein* (*Popular Astronomy*, No. 64), I have again called attention to the change. This change of form must have an important bearing upon any theories of the *Gegenschein*.

"Throughout the month of September it (the *Gegenschein*) is large and round and very distinct, its diameter being as much as 20°.

"About the first of October it is essentially round and large, but it soon undergoes a striking change. By the 4th or 5th of the month it is slightly elongated. From about the 10th or 11th it becomes very much elongated along the ecliptic, and especially so about the 18th, when it seems to be a mere swelling in the zodiacal band, stretching a great distance along the ecliptic."

I have carefully watched for this change during the present month, and the observations have fully verified the above statements.

In September it was large and round and very dense, being at least 20° in diameter.

In the middle of September a feeble zodiacal band was seen running from it to the east and passing between the *Pleiades* and *Hyades*. This band was about 5° or 6° in diameter. There was no band to the west.

The first few days of October the *Gegenschein* was large and dense and round. By October 6 it seemed slightly elongated in the ecliptic. By the 7th and 8th it appeared smaller in a north and south direction and extended along the ecliptic. By October 12 it was very much elongated in the ecliptic, being 20° to 25° in length, but not more than 10° in width.

I send this note, because the *Gegenschein* has attracted considerable attention of late, and this change of form must be taken into account in any theories tending to explain the phenomenon.

Yerkes Observatory, Williams Bay, Wis., 1899 *Oct.* 17.

OBSERVATIONS OF MINOR PLANETS AND COMET a 1899 I.

MADE AT THE SAYRE OBSERVATORY, SO. BETHLEHEM, PA.,

BY JOHN H. OGBURN.

1899 Bethlehem M.T.	*	No. Comp.	Object — * $\Delta\alpha$	Object — * $\Delta\delta$	Object's Apparent α	Object's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
				(287) Nephthys.				
	h m s		m s	′ ″	h m s	° ′ ″		
April 27	8 58 35	1	7	−2 17.46	+1 14.0	14 3 38.05	+ 4 53 48.2	n9.464	0.722
28	9 4 31	2	8	+2 32.01	−2 59.7	14 2 44.87	+ 4 59 11.5	n9.463	0.722
29	8 26 51	2	9	+1 31.50	+1 55.2	14 1 44.37	+ 5 4 6.4	n9.509	0.723
May 4	9 32 37	3	9	−1 14.01	+2 48.5	13 57 40.79	+ 5 25 42.6	n9.255	0.713
9	9 27 7	4	11	+0 53.42	+4 1.2	13 53 49.31	+ 5 40 24.7	n9.111	0.777
				(17) Thetis.				
May 15	10 58 51	5	8	+2 15.47	−1 10.7	15 31 18.29	− 8 51 38.8	n9.061	0.531
				COMET a 1899 I.				
June 3	9 13 19	6	18	−0 51.47	+2 58.7	17 15 33.91	+53 55 2.3	n9.778	n9.079
7	9 51 48	7	6	+0 25.49	−0 59.6	16 11 26.26	+47 49 55.6	n9.320	n9.987
8	9 18 18	8	6	+0 5.46	−5 15.0	15 59 47.86	+46 13 42.4	n9.406	n9.703

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	14 5 52.23	+3.28	+ 4 52 50.2	−16.1	Boss, Albany A.G. Catal. 4891
2	14 0 9.64	+3.22	+ 5 2 28.6	−17.4	M_1 9848
3	13 58 51.66	+3.17	+ 5 23 10.9	−16.8	M_1 9787
4	13 52 52.65	+3.24	+ 5 36 40.0	−16.5	M_1 9678
5	15 28 59.27	+3.55	− 8 50 35.5	+ 7.4	$\frac{1}{3}$ (2 Gould A.C. + Brux.)
6	17 16 22.14	+3.24	+53 52 8.9	− 5.3	Rogers, Cambr. A.G. Catal. 5223
7	16 10 57.48	+3.29	+47 50 59.2	− 4.0	Bonn VI, 2319
8	15 59 39.12	+3.28	+46 19 1.1	− 3.7	v *Herculis*

June 3, 7, 8, $\Delta\alpha$ measured directly.

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THE POLAR COMPRESSION OF *JUPITER*,

By W. S. ADAMS.

The recent careful determination by Professor BARNARD of the motion of the line of apsides of the fifth satellite of *Jupiter* renders possible a determination of the polar compression of the planet which may be of interest in view of the numerous micrometric observations of the same quantity.

The expression for the potential of *Jupiter* upon the satellite may be written*

$$V = \frac{fM}{r}\left[1+\left(\frac{a_1}{r}\right)\left(e_1-\tfrac{1}{2}\phi\right)\left(\tfrac{1}{3}-\sin^2\delta\right)\right] = \frac{fM}{r}+V_1$$

where M is the mass of *Jupiter*, a_1 its equatorial radius, e_1 its polar compression, ϕ the ratio between the centrifugal force and weight at the equator, r the distance between the centers of the two bodies, and δ the satellite's declination referred to the planet's equator. Observation shows δ to be extremely small, and it may be neglected without sensible effect upon the result. V_1 is the perturbing function due to the flattening of *Jupiter* and hence for the motion of the perijove we have†

$$\frac{d\varpi}{dt} = \frac{\sqrt{1-e^2}}{na^2e}\frac{\partial V_1}{\partial e} = \frac{fMa_1^2}{3na^2e}\left(e_1-\tfrac{1}{2}\phi\right)\frac{\partial\frac{1}{r^3}}{\partial e}$$

Omitting periodic terms, and reducing,

$$\frac{d\varpi}{dt} = n\left(\frac{a_1}{a}\right)^2\left(e_1-\tfrac{1}{2}\phi\right),\ \text{or,}\ I\varpi = \left(\frac{a_1}{a}\right)^2\left(e_1-\tfrac{1}{2}\phi\right)nt$$

in which a denotes the semi-major axis of the satellite's orbit, and n its mean motion.

To compute $\frac{1}{2}\phi$ on the basis of the non-homogeneous character of *Jupiter* we find the formulas

$$\tfrac{5}{4}\phi = \tfrac{1}{2}\lambda'^2-\tfrac{3}{4}\lambda'^4+\tfrac{5}{16}\lambda'^6-\tfrac{35}{128}\lambda'^8+\ldots$$

where $\lambda'^2 = \tfrac{15}{2}v'+\tfrac{6}{7}(\tfrac{15}{2}v')^2+\tfrac{37}{49}(\tfrac{15}{2}v')^3+\tfrac{7850}{11319}(\tfrac{15}{2}v')^4+\ldots$

and $v' = 0.001150\left(\frac{T}{T'}\right)^2\left(\frac{\rho}{\rho'}\right)$

Taking the values of $\frac{\rho}{\rho'}$ and T and T' given by the *Annuaire du Bureau des Longitudes* for 1899, we find

$$\tfrac{1}{2}\phi = 0.04214$$

Furthermore, $\frac{a}{a_1} = 2.55$, and $n = \frac{2\pi}{\tau} = 722^\circ.6316$, taking the day as the unit of time. For the daily motion of the perijove, $I\varpi$, Professor BARNARD finds a value of $2^\circ.465$, by combining observations extending over the seven years since his discovery of the satellite in 1892.

The substitution of these quantities gives

$$e_1 = 0.06432 = \tfrac{1}{15.55}$$

A result in close agreement with the heliometer measures of BESSEL and SCHUR, and the double-image micrometer measures of KAISER.*

This result may be applied to the investigation of the principal moments of inertia of *Jupiter*.

If we denote by A and C the moments of inertia of the planet with respect to its axis of rotation and to an axis in the plane of its equator, we find

$$\frac{A-C}{M} = \tfrac{2}{3}a_1^2\left(e_1-\tfrac{1}{2}\phi\right)$$

Using the earth's mass and its equatorial radius as units this formula gives

$$A-C = 560.484$$

An assumption as to the law of the increase of density from the surface to the center of the planet will render possible the solution of the well-known form of CLAIRAUT's equation

$$\frac{A-C}{A} = \left(e_1-\tfrac{1}{2}\phi\right)\frac{\int \rho\, d(a^5)}{\int \rho\, d(a^5)}$$

whence, by combination with the above value of $A-C$, A and C may be determined.

Yerkes Observatory, 1899 *November* 4.

*TISSERAND, *Mécanique Céleste*, t. II, p. 210.

†TISSERAND, *Mécanique Céleste*, t. I, p. 169.

*See Professor BARNARD's summary in *A.J.* 325, 1894.

ELEMENTS OF *EROS*,

BY HENRY NORRIS RUSSELL.

Five normal places have been formed from observations made at the Chamberlin and Lick Observatories, and published in *A.J.* 463, 464 and 469. My elements, published in *A.J.* 457, do not represent them satisfactorily. The value of μ there given, being that deduced by Dr. CHANDLER from five years' observations, has been retained, as have also the values of ☊ and i, which were closely determined by the observations of August–December, 1898. The most probable values of the corrections of the other elements have been determined by least-squares.

The resulting elements are as follows:

Epoch = 1898 August 31.5 Greenwich M.T.

$$M = 221^\circ\ 37'\ 2''.0$$

$$\left.\begin{aligned}\omega &= 177\ 39\ 10.6\\ \Omega &= 303\ 29\ 57.3\\ i &= 10\ 49\ 34.0\end{aligned}\right\}1898.0 \qquad \begin{aligned}\varphi &= 12^\circ\ 52'\ 14''.2\\ \mu &= 2015''.2326\\ \log a &= 0.1637876\end{aligned}$$

FOR EQUATOR OF 1899.0.

$$\begin{aligned}x &= [9.9946090]\,r\,\sin(v+211^\circ\ 38'\ 29''.0)\\ y &= [9.9414807]\,r\,\sin(v+116\ 34\ 57.7)\\ z &= [9.7081149]\,r\,\sin(v+137\ \ 7\ 28.7)\end{aligned}$$

The new normal places, and those previously given in *A.J.* 457, are represented as follows:

OBSERVED NORMALS 1898.0

1898 Gr. M.T.	No. Obs.	α	δ	O — C α	O — C δ
		h m s	° ′ ″	s	″
Aug. 17.5	35	21 20 50.89	− 6 24 27.3	+0.01	−0.6
24.5	26	21 8 16.15	− 6 18 7.4	−0.01	+1.9
Sept. 1.5	19	20 55 35.58	− 6 18 12.6	+0.08	+0.3
13.5	41	20 41 54.33	− 6 21 4.2	−0.13	−1.1
23.5	14	20 36 19.66	− 6 20 43.0	−0.16	−0.6
Oct. 11.5	2	20 39 2.16	− 6 2 3.1	−0.13	−1.0
Nov. 11.5	4	21 12 34.47	− 4 5 16.6	−0.28	−2.6
Dec. 8.5	4	22 0 14.48	− 0 38 4.7	+0.09	+1.4
28.5	2	22 44 0.54	+ 2 57 39.2	−0.05	+2.1

OBSERVED NORMALS 1899.0

1899	No. Obs.	α	δ	O — C α	O — C δ
Mar. 1.5	4	1 37 17.37	+17 27 43.7	−0.05	+2.1
15.5	3	2 24 35.74	+20 20 57.6	−0.02	−0.4
Apr. 2.5	8	3 30 28.49	+23 5 43.4	−0.05	−0.2
May 4.5	10	5 37 13.54	+23 46 55.3	+0.10	+1.1
20.5	8	6 41 8.41	+21 45 0.5	+0.01	+1.1

Princeton University, 1899 *Oct.* 30.

ORBIT OF *NEPTUNE'S* SATELLITE,

BY STIMSON J. BROWN.

FROM OBSERVATIONS WITH THE 26-INCH EQUATORIAL OF THE U.S. NAVAL OBSERVATORY.

(Communicated by Prof. WM. HARKNESS, U.S.N., Astronomical Director.)

The observations of the satellite, extending from 1897 Oct. 13, to 1898 Mar. 5, were made on every clear night during that interval when it was visible. Besides the forty successful measures, there were seventeen clear nights on which the satellite was invisible. The image of the planet was seldom well defined, sometimes so agitated that it appeared little like a planetary disk; except on a few nights, the satellite was very difficult — faint, unsteady and diffuse. Only rarely were the conditions of transparency and steadiness of the air such that the satellite was easily visible.

Much of the poor seeing was ascribed to the radiations from the thick marble walls of the dome building, the massive concrete pier, and the cement floor of the basement. The importance of the last two causes may be seen from the fact that, during the winter, the temperature of the ground immediately underneath the cement floor remains constant at 57° *F.* These unfavorable conditions were increased by the necessity of keeping the temperature of the basement above the freezing point for the protection of the hydraulic machinery of the elevating floor.

During the past summer (1899) the pier and the basement floor and walls have been covered with an insulating sheathing, consisting of two thicknesses of matched pine with a layer of tarred paper between. It will therefore be possible, during the coming winter, to determine to a certain extent how much of the bad seeing experienced in the winters of '97 and '98 was due to the building, and how much to general atmospheric causes.

A Steinheil achromatic eyepiece, giving a magnifying power of 606, was used throughout. All measures were referred to the estimated center of the planet's disk, and the distances were obtained by the method of double-distance measures. The micrometer wires were illuminated a dull red color, by means of a small hand lamp, as in all measures with this instrument. In the experienced hands of Mr. GEORGE ANDERSON, it is tolerably satisfactory; but I was impressed with the decided advantages of the system of electric illumination as installed on the Yerkes 40-inch telescope. Not only is the intensity of the illumination easily controlled by the observer, but the amount of stray light in the field is so small as to be practically inappreciable.

The observations, given below in tabular form, need no special explanation. The seeing is indicated on a scale of 5, 3 representing an average condition of image of this

particular object, however, so that it is not a measure of the atmospheric conditions generally; the weights were based on the remarks in the observing books, the scale being purely arbitrary. No observation has been rejected or altered, and the weights assigned are strictly in accordance with the original notes.

1897–8. OBSERVATIONS *Neptune's* SATELLITE — 26-INCH TELESCOPE, NAVAL OBSERVATORY.

W. M. Date		Position-Angle	No. Settings	Wt.	W. M. T.	Distance	No. Settings	Wt.	Seeing	Remarks
1897	h m	°			h m	″				
Oct. 13	14 56.5	256.95	8	1.33	14 58.0	16.82	6	1.33	4	Par. 354°.0
17	14 17.0	30.90	8	1.00	14 19.5	12.91	6	1.00	3	Seeing poor, very unsteady, Par. 354°.18
18	14 11.5	302.07	8	1.00	14 14.0	12.04	6	1.00	3	Faint but steady, Par. 173°.98
29	13 19.5	15.35	4	0.67	13 38.5	11.72	6	0.67	3–2	Clouded over, p. not very good
30	13 19.5	288.59	8	1.33	13 20.0	13.42	6	1.33	4	
Nov. 3	13 26.0	62.73	8	1.00	13 27.0	15.94	6	1.00	3	
4	13 0.5	5.24	8	1.00	13 1.0	10.66	6	1.00	3	
6	12 32.0	241.70	8	1.00	12 32.5	16.76	6	1.00	3	Bright moonlight, satellite very difficult
13	12 4.5	171.95	8	1.00	12 5.5	10.48	8	1.00	2	Very faint, unsteady, diffuse
17	12 2.8	272.71	8	1.00	12 3.0	15.69	8	1.00	2	Unsteady, diffuse, bad
20	12 6.8	90.10	8	1.33	12 8.5	15.64	8	1.33	3	Fine seeing but satellite faint, Par. 174°.02
23	11 45.8	268.04	9	1.00	11 47.5	16.26	8	1.00	2	Cold N.W. wind
24	11 23.0	228.44	8	1.00	11 24.0	15.34	6	1.00	4	
27	11 10.8	44.21	8	1.00	11 11.0	14.56	8	1.00	2	Par. 174°.0
29	11 4.2	264.66	8	1.00	11 4.5	16.70	8	1.00	3	
Dec. 7	11 9.8	128.80	8	1.00	11 11.0	11.29	8	1.00	2	Bright moon, sat. very faint. Par. 94°.02
11	9 23.6	257.22	4	1.33	9 32.5	16.97	8	1.33	1	Fine, but thick, satellite easily visible
12	9 15.0	214.15	8	1.00	9 15.0	13.29	8	1.00	2	Planet wooly, satellite faint, Par. 174°.0
15	9 38.5	24.51	8	0.33	9 37.0	12.71	8	0.33	1	"The worst seeing in which I have ever observed"
16	9 31.0	300.28	4	1.00	9 51.0	12.41	8	1.00	2	Thick, very difficult, clouds
23	9 11.8	248.05	8	1.00	9 12.0	17.13	8	1.00	3	Clear, high wind, telescope steady
26	9 36.5	65.62	8	1.00	9 37.0	16.44	8	1.00	3	Observation difficult
30	9 41.2	183.68	8	1.00	9 46.5	11.03	8	1.00	2	Very poor, difficult, unsteady, sat. v.f.
1898										
Jan. 1	8 53.0	60.69	8	1.00	8 53.6	16.14	8	1.00	2	High wind, telescope sways, very unsteady and diffuse
4	7 57.2	240.60	8	1.33	7 56.5	16.71	8	1.33	3	Par. 174°.0
5	8 58.0	175.45	8	1.33	8 59.5	10.65	8	1.33	4	Bright moon, very faint, planet very steady
8	8 32.5	351.85	8	1.00	8 31.5	10.50	8	1.00	2	Very poor, faint, unsteady, Par. 174°.0
13	8 8.5	52.10	8	0.67	8 8.5	15.11	8	0.67	3–2	Seeing grows very bad
17	9 34.5	148.42	4	0.67	9 51.5	10.28	8	0.67	2	Faint, clouds, can't finish, v.f.
18	7 34.0	87.95	8	1.33	7 33.5	15.39	8	1.33	4	Seeing very good
21	7 46.5	264.82	8	1.00	7 51.0	16.33	8	1.00	3	Obs. broken by clouds, sat. distinct at times
24	7 30.5	82.16	8	1.00	7 30.0	15.90	8	1.00	3	
28	7 26.3	218.66	8	1.00	7 26.5	14.05	8	1.00	2	Very poor
Feb. 7	7 9.5	299.56	8	1.00	7 9.0	11.78	8	1.00	3	Par 174°.0
9	7 35.5	204.01	8	1.00	7 36.0	12.07	8	1.00	3	Very faint
10	7 1.5	117.32	8	1.33	7 2.0	11.84	8	1.33	4	Faint but steady
12	7 32.5	17.82	8	1.00	7 32.0	11.60	8	1.00	2	Windy, very faint, unsteady, diffuse
13	6 37.8	292.15	8	1.00	6 38.5	12.68	8	1.00	2–3	Very faint at first
26	7 32.0	236.77	8	1.00	7 32.0	15.65	8	1.00	3	
Mar. 5	7 55.5	156.30	8	1.00	7 54.5	10.06	8	1.00	3	

The computed places and the coefficients of the equations of condition were derived from MARTH's well-known formulas, with some slight modifications, which I have found of considerable convenience: the coefficients of MARTH's formulas have all been divided by the assumed mean distance, a, which gives all results in seconds of arc. The following table gives the G. M. Time, corrected for aberration, the observed position-angles reduced to the epoch of the corresponding distances, and the residuals in s and p resulting from the substitution, in the equations of condition, of the corrections derived from the solution of the normal equations. These, with the results of their solution, follow immediately after the table.

The assumed elements for 1898.0 are,

$$\Gamma = 308.25$$
$$J = 117.80$$
$$N = 186.50$$
$$n = 61.25712$$
$$a = 16''.30$$

Neptune's Satellite 1897–8.

Greenw. Mean Date	Position-Angle Observed	Position-Angle Computed	Distance Observed	Distance Computed	C—O sdp	C—O ds	$\sqrt{pv}$ V_p	$\sqrt{pv}$ V_s
1897 h m	°	°	"	"	"	"	"	"
Oct. 13 15 54.4	256.90	258.12	16.82	16.60	+0.35	−0.22	+0.17	−0.16
17 15 16.4	30.85	31.06	12.91	12.73	+ .05	− .18	− .28	− .38
18 15 11.4	301.95	304.18	12.04	11.95	+ .37	− .09	+ .01	+ .03
29 14 36.7	14.29	14.96	11.72	11.45	+ .13	− .27	− .20	− .35
30 14 18.3	288.59	290.17	13.42	13.38	+ .37	− .04	+ .06	+ .12
Nov. 3 14 25.6	62.70	63.83	15.94	16.50	+ .33	+ .56	+ .11	+ .40
4 13 59.7	5.19	6.65	10.66	11.00	+ .28	+ .34	− .11	+ .21
6 13 31.4	241.70	242.87	16.76	16.46	+ .34	− .30	+ .20	− .27
13 13 4.9	171.87	173.14	10.48	10.57	+ .23	+ .09	+ .18	+ .06
17 13 2.6	272.71	273.53	15.69	15.42	+ .22	− .27	− .04	− .14
20 13 8.3	90.04	90.59	15.64	15.76	+ .15	+ .12	.00	+ .05
23 12 47.4	267.98	268.54	16.26	15.99	+ .16	− .27	− .08	− .15
24 12 24.0	228.40	228.82	15.34	15.10	+ .11	− .24	+ .01	− .24
27 12 11.1	44.21	46.28	14.56	14.79	+ .42	+ .23	+ .14	+ .03
29 12 4.7	264.64	264.59	16.70	16.37	− .04	− .33	− .26	− .23
Dec. 7 12 11.4	128.73	130.61	11.29	11.49	+ .30	+ .20	+ .22	+ .15
11 10 32.9	256.98	257.28	16.97	16.85	+ .09	− .12	− .12	− .05
12 10 15.4	214.15	214.75	13.29	13.33	+ .14	+ .04	+ .07	+ .03
15 10 37.4	24.60	28.91	12.71	12.81	+ .96	+ .10	+ .36	− .06
16 10 51.4	299.24	300.63	12.41	12.23	+ .32	− .18	− .04	− .05
23 10 12.3	248.05	248.36	17.13	16.92	+ .09	− .21	− .07	− .16
26 10 37.1	65.60	65.32	16.44	16.80	− .08	+ .36	− .30	+ .21
30 10 46.4	183.34	184.59	11.03	10.96	+ .24	− .07	+ .19	− .10
1898								
Jan. 1 9 53.3	60.69	61.65	16.14	16.56	+ .28	+ .42	+ .05	+ .26
4 8 56.2	240.61	240.79	16.71	16.49	+ .05	− .22	− .10	− .22
5 9 59.1	175.37	176.34	10.65	10.62	+ .18	− .03	+ .15	− .07
8 9 31.0	351.88	352.33	10.50	10.51	+ .08	+ .01	− .33	− .07
13 9 7.6	52.10	52.73	15.11	15.66	+ .17	+ .55	− .07	+ .30
17 10 50.2	147.24	148.74	10.28	10.50	+ .27	+ .22	+ .17	+ .14
18 8 32.1	87.95	88.26	15.39	15.72	+ .09	+ .33	− .07	+ .29
21 8 49.3	264.70	265.14	16.33	16.03	+ .12	− .30	− .10	− .19
24 8 28.0	82.16	83.20	15.90	16.19	+ .29	+ .29	+ .12	+ .20
28 8 24.1	218.66	219.27	14.05	13.93	+ .15	− .12	.07	− .12
Feb. 7 8 5.4	299.60	301.35	11.78	11.79	+ .36	+ .01	+ .01	+ .14
9 8 32.2	203.98	203.67	12.07	12.14	− .07	+ .07	− .13	+ .05
10 7 58.1	117.28	117.20	11.84	12.13	− .02	+ .29	− .13	+ .27
12 8 27.8	17.86	19.43	11.60	11.75	+ .32	+ .15	− .03	− .04
13 7 34.2	292.12	294.07	12.68	12.41	+ .43	− .27	+ .10	− .13
26 8 26.0	236.77	237.06	15.65	15.85	+ .08	+0.20	− .04	+ .22
Mar. 5 8 47.5	156.38	159.00	10.06	10.06	+0.46	.00	+0.40	−0.04

	SJ	SN	SU_0	ξ	η	da	n
	+12.9922	+1.3847	− 3.6338	− 0.8748	+ 1.0457	− 9.4993	+0.4486
		+8.7687	− 4.4333	+ 2.1559	+ 0.0545	− 2.9549	+0.4820
			+29.4107	+ 4.9988	− 1.9441	+ 0.0143	−7.1362
				+52.2209	+17.6319	+ 2.7436	−3.7940
$[nn6]$	2″.5244				+96.3191	+ 6.6331	−8.0509
$[vv]$	2″.5268					+30.7590	+0.4834
							+5.0940

$$SJ = +0''.003 \pm 0''.040 = +0^\circ.010 \pm 0^\circ.140$$
$$SN = +\ .058 \pm\ .044 = +\ .204 \pm\ .154$$
$$SU_0 = +\ .255 \pm\ .024 = +0.895 \pm 0.084$$
$$\xi = +\ .020 \pm\ .018$$
$$\eta = +\ .087 \pm\ .013$$
$$da = -0.030 \pm 0.026$$

$$\tau_1 \pm 0''.1229$$

Applying these corrections to the assumed elements, there is derived for the mean epoch, Dec. 20^d.4725 G.M.T., 1897, the following

CORRECTED ELEMENTS FOR 1898.0.

$$U = 309°.15 \pm 0°.084$$
$$J = 117°.81 \pm 0°.140$$
$$N = 186°.70 \pm 0°.154$$
$$\pi = 167°.29 \pm 11°.5$$
$$e = 0.00547 \pm 0.00262$$
$$a = 16''.270 \pm 0''.026$$

The probable error of a single observation is 0″.1229.

From the difficulties encountered in the observations, I had found that the results might be affected with large probable errors. The observations prove, however, to have been unusually good, exceeding a little in accuracy the series made during the same opposition by Prof. BARNARD with the 40-inch Yerkes telescope, the results of which are given by Prof. A. HALL in this Journal (Vol. XIX, p. 66).

The results of the two series agree closely, even in the uncertain quantities π and e. This agreement, as well as the results of a discussion of all the elements of the satellite since 1848, convince me that these two quantities are real, and as close an approximation to the truth as their nature would admit.

I am greatly indebted to Mr. M. E. PORTER, computer, who has made nearly all the computations on this paper, as a voluntary labor, outside of his official duties in the observatory.

U.S. Naval Observatory, Washington, 1898 *Dec.* 2.

MAXIMA AND MINIMA OF LONG PERIOD VARIABLES,

BY J. A. PARKHURST.

294. *W Cassiopeae.*

Continuing the series reported in *A.J.* 458, the star fell slowly from 10^M.0, 1899 Jan. 24, to a minimum, 12^M.1, 1899 May 17, then rose more rapidly to 10^M.1, 1899 Aug. 6. I have 12 observations between the above dates.

4471. *T Canum Venaticorum.*

Since the minimum reported in *A.J.* 456, I have 24 observations between 1898 Aug. 27 and 1899 Aug. 5, yielding a maximum at 8^M.8, 1898 Nov. 23, and a minimum at 11^M.8, 1899 April 20. The light curves for both phases were regular and the dates quite definite. From continuous observations of three maxima and three minima I find the period, from maxima 286 days, from minima 290 days; $M-m$, 148 days.

6449. *T Draconis.*

I have 29 observations since the maximum reported in *A.J.* 458, yielding a well defined minimum 1899 Feb. 21 and a maximum Aug. 15. The magnitudes were 11.4 and 8.5 at the two phases, respectively. The variable was fainter than its 10^M.5 companion from 1898 Nov. 25 to 1899 June 1. The light curve at maximum was much sharper than usual.

6549. *W Lyrae.*

Continuing the series reported in *A.J.* 465, I have 29 observations between 1899 Feb. 15 and Nov. 14. These yield a maximum at 8^M.0 June 4, and a minimum at 11^M.8 Sept. 4.

6399. *U Draconis.*

This variable has been followed continuously since its discovery. I have 39 observations since the report in *A.J.* 456, yielding a minimum 1899 April 5 at 12^M.8 (the limit of the 6.2-inch reflector), and a maximum Sept. 4 at 9^M.3. The maximum was more sharply defined than the minimum and the rise more rapid than the decline. The interval between my two observed maxima is 329 days, between the two minima 324 days; the mean being 7 days less than the period given by Dr. HARTWIG in *A.N.* 3553.

7085. *RT Cygni.*

Since the maximum reported in *A.J.* 465, I have 24 observations yielding a minimum at 11^M.9, 1899 May 27, and a maximum at 7^M.4 Aug. 26.

7379. *ST Cygni.*

Since the reappearance from the minimum reported in *A.J.* 458 I have 27 observations, ending 1899 Nov. 6. The rise towards maximum was interrupted by a "stand still" at 10$\frac{1}{4}^M$ from 1899 Mar. 1 to April 20. A similar interruption, but one-third as long, can be seen in the curve preceding the 1898 maximum. After this halt the star rose to a well defined maximum at 9^M.5, 1899 May 30, then fell steadily till last certainly seen Oct. 2, at about 12^M.8. The interval between the two maxima was 349 days, which would be shortened a few days if the halt in the curve were smoothed out.

7492. *RZ Cygni.*

In continuation of the series reported in *A.J.* 458 I have 29 observations between 1898 Nov. 1 and 1899 Nov. 5. The star fell slowly and irregularly from 11^M to a minimum at 12^M.8, 1899 April 15, then rose more rapidly and quite steadily to a maximum 1899 Sept. 2, at 9^M.8, the brightest I have observed. It had fallen to 10.8 magnitude at the last observation. At maximum the variable was, to my eye, 0^M.3 fainter than the neighboring DM. star +46°3078, which is 9^s.1 preceding the variable. The magnitude at

minimum depends on the scale which I have given in *A.N.* 3579, assuming $12^M.8$ as the limit of the 6.2-inch reflector.

ANDERSON'S *Variable in Pegasus.*

R.A. $21^h 14^m 7^s.5$, Decl. $+13° 50' 17''$, (1855).

This variable which was announced in *A.N.* 3521, and of which I reported a maximum and minimum in *A.J.* 465, has been followed through another complete period. I have 20 observations between 1899 April 1 and Nov. 15. yielding a minimum at $12^M.5$, 1899 June 10, and a maximum at $9^M.1$ Sept. 18, followed by a fall to $11^M.1$ at the last comparison. The light curve is regular. The interval between the two maxima is 205 days, and between the two minima 199 days; the two values of $M-m$ are 91 and 100 days.

7792. *SS Cygni.*

Since the report in *A.J.* 465 I have observed the following, in which T represents the time of passing $9^M.35$ on the rise.

Epoch	T	Max.	Mag.
7, short	1899 July 2.0	July 3.8	8.5
7, long	Aug. 23.0	Aug. 26.6	8.3
8, short	Oct. 25.0	Oct. 26.8	8.5

The three maxima are covered by 67 observations.

8324. *V Cassiopeae.*

From 30 observations between 1899 Feb. 1 and Oct. 25 I find a minimum at $12^M.4$ April 16, and a maximum Aug. 7 at $7^M.6$. The light curves present the usual regular features.

OBSERVATIONS OF *ENCELADUS*,

MADE WITH THE 26-INCH REFRACTOR AT THE LEANDER McCORMICK OBSERVATORY,

BY HERBERT R. MORGAN.

Enceladus-Tethys.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s ″
June 29	9 24 43	249.35	9 29 33	56.87
	9 31 1	250.35	9 30 41	56.86
	10 58 15	259.14	11 3 21	64.29
	11 8 38	260.11	11 4 29	65.07
30	8 35 15	87.66	8 40 20	42.66
	8 45 40	88.00	8 41 35	42.79
	10 24 19	96.08	10 29 15	40.75
	10 34 3	96.86	10 30 29	40.41
July 11	9 24 57	290.09	9 30 57	10.79
	9 37 55	290.11	9 32 29	10.54
18	11 12 35	255.98	11 17 10	65.76
	11 22 43	256.80	11 18 31	66.10

Enceladus-Dione.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s ″
June 29	9 6 11	191.04	9 12 19	29.14
	9 18 4	194.47	9 13 39	29.78
	10 43 11	213.43	10 47 37	29.87
	10 53 11	215.58	10 48 29	29.91
30	9 3 59	261.44	9 8 13	38.11
	9 12 9	261.69	9 9 10	38.51
	11 0 1	267.03	11 4 39	46.50

Enceladus-Dione. — Cont.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s ″
June 30	11 9 38	267.48	11 5 55	47.00
July 11	9 44 37	267.20	9 50 33	44.34
	9 56 41	267.63	9 51 53	43.29
18	10 36 17	154.10	10 42 42	36.26
	10 50 23	158.00	10 43 49	36.81
	11 43 19	170.25	11 47 29	32.31
	11 52 33	171.87	11 49 5	32.56

Enceladus-Rhea.

1899	Eastern M.T. h m s	p °	Eastern M.T. h m s	s ″
June 29	9 41 51	271.11	9 47 33	115.09
	9 54 25	271.46	9 19 7	115.29
	11 16 27	275.09	11 21 29	116.70
	11 26 48	274.86	11 22 52	117.00
30	8 48 51	351.79	8 53 28	20.80
	8 59 33	351.63	8 54 33	20.92
	10 43 20	341.44	10 47 15	20.86
	10 52 54	341.49	10 48 19	20.89
July 11	10 22 3	135.02	10 28 16	68.17
	10 26 16	137.12	10 30 22	68.39
18	10 54 25	300.48	10 59 39	49.56
	11 5 9	300.70	11 1 2	48.97

OBSERVATIONS OF COMET *e* 1899 (GIACOBINI),

MADE AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,

BY C. D. PERRINE.

1899 Mt. Hamilton M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Telescope
			m s	′ ″	h m s	° ′ ″			
Oct. 2 8 6 35	1	d10 , 8	−0 9.63	+11 5.6	16 32 59.70	−4 12 17.6	9.630	0.744	12
3 7 11 54	2	10 , 8	−1 43.37	+ 7 34.9	16 34 22.11	−3 53 35.3	9.569	0.749	12
4 6 59 24	3	d10 , 8	+0 6.08	− 4 17.3	16 35 46.73	−3 34 39.5	9.547	0.749	12
6 7 21 25	5	d10 , 8	−0 35.70	− 0 9.0	16 38 39.99	−2 56 33.3	9.592	0.743	12
7 7 38 46	6	11 , 8	+1 31.45	− 5 55.2	16 40 8.02	−2 37 49.1	9.615	0.740	12
16 6 38 53	7	d10 , 8	−0 21.73	+ 2 47.2	16 53 13.68	+0 1 44.1	9.567	0.728	12

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 33 6.56	+2.77	−4 23 22.2	−1.0	M_1 12824
2	16 36 2.73	+2.75	−4 1 9.6	−0.6	½(Schjellerup 5905 + M_1 12900)
3	16 35 37.93	+2.72	−3 30 21.7	−0.5	Micrometer comparison with *4
4	16 34 23.99	+2.71	−3 25 13.5	−0.6	Schjellerup 5893
5	16 39 13.00	+2.69	−2 56 24.3	−0.0	" 5931
6	16 38 33.90	+2.67	−2 31 54.0	+0.1	" 5925
7	16 53 32.83	+2.58	−0 1 4.7	+1.6	Micrometer-comparison with *8
8	16 58 31.06	+2.60	−0 0 8.3	+2.1	Radcliffe$_3$ 4434

d indicates that $\Delta\alpha$ was measured directly with the micrometer. Comet is about 11th magnitude, 1′ diameter, with a very faint nucleus. *October* 2, Owing to a misprint in the code book opposite the word "anoint," the date of this observation was translated 2.6658 by the receivers, instead of 2.6758 as it should have been.

Mt. Hamilton, California, 1899 *October* 21.

THE SECULAR PERTURBATIONS OF THE *EARTH* ARISING FROM THE ACTION OF *MERCURY*,

BY ERIC DOOLITTLE.

The elements employed in this computation are from Dr. G. W. HILL's "*New Theory of Jupiter and Saturn,*" pp. 192 and 554.

Earth	*Mercury.*
$\pi = 100°\ 21'\ 39''.73$	$\pi' = 75°\ 7'\ 13''.62$
$i = 0\ \ 0\ \ 0.00$	$i' = 7\ \ 0\ \ 7.71$
$\Omega = \ldots\ldots$	$\Omega' = 46\ 33\ \ 8.63$
$e = 0.01677114$	$e' = 0.20560476$
$n = 1295977''.416$	$n' = 5381016''.260$
$\log a = 0.0000000$	$\log a' = 9.5878217$
$m = 1 \div 327000$	$m' = 1 \div 7500000$

Epoch = 1850.0 G.M.T.

The orbit of the *Earth* was divided into twelve parts with regard to the eccentric anomaly, and the work carried through in accordance with Dr. HILL's first modification of GAUSS's method, exactly as in the case of the perturbations of *Venus* and *Mercury* heretofore published. The agreement of the final sums, while in general not sufficiently exact for verification, was more nearly so then in the case of *Mars* on *Mercury*, or *Mercury* on *Venus*, when but twelve points of division were employed. Such test equations as were known were applied, and the work was also duplicated from the beginning with such modifications of the formulas as could easily be made.*

The values of the preliminary constants and of the resulting differential coefficients are as follows:

$$
\begin{array}{llll}
I = 7°\ 0'\ 7''.71 & & \log k = p9.9992608 \\
\Pi = 53\ 48\ 31.10 & & \log k' = p9.9974965 \\
\Pi' = 28\ 34\ \ 4.99 & & \log c = p7.8017096 \\
K = 25\ 25\ 13.33 & & c = 0.0063344603 \\
K' = 25\ \ 3\ 36.28 & &
\end{array}
$$

		log coeff.
$\left[\dfrac{de}{dt}\right]_{00} = -$	$8710''.1780\, m'$	$n3.9400270$
$\left[\dfrac{d\chi}{dt}\right]_{00} = \left[\dfrac{d\pi}{dt}\right]_{00} = -$	$824986.23\ m'$	$n5.9164467$
$\left[\dfrac{dp}{dt}\right]_{00} = +$	$18814.333\ m'$	$p4.2744888$
$\left[\dfrac{dq}{dt}\right]_{00} = -$	$15740.112\ m'$	$n4.1970078$
$\left[\dfrac{dL}{dt}\right]_{00} = +$	$2948201.7\ m'$	$p6.4695572$

The equations of Mr. INNES, $\sin q \cdot \frac{1}{2} B_1^{(r)} + \cos q \cdot B_0^{(r)} = 0$, is found to give the residual $+0.000000006$.

If we adopt for m' the value given above, there finally results:

$$\left[\frac{de}{dt}\right]_{00} = -0''.0011613570$$

$$\left[\frac{d\pi}{dt}\right]_{00} = -0.10999815$$

$$\left[\frac{dp}{dt}\right]_{00} = +0.0025085775$$

$$\left[\frac{dq}{dt}\right]_{00} = -0.0020986812$$

$$\left[\frac{dL}{dt}\right]_{00} = +0.39309355$$

These results have been published by LEVERRIER (*Annales de l'Observatoire de Paris*, Tome II, page 59, and Tome IV, pages 11 and 12), and also to three significant figures by NEWCOMB ("*Secular Variations of the Orbits of the Four Inner Planets*," pages 336 and 337). The values of dp and dq have been computed also by Dr. HILL ("*New Theory*," pages 511 and 512). If we reduce all results to the above value of m', the various coefficients compare as follows:

* The following obvious error occurs in ZECH's "*Tafeln der Additions-und Subtractions-Logarithmen.* Second edition: on page 694, 90386 should be 00386.

	LeVerrier	Newcomb	Hill	Method of Gauss
	″	″	″	″
$\left[\frac{de}{dt}\right]_{00} =$	−0.001 16	−0.001 16	. . . . . .	−0.001 161 36
$\left[\frac{dp}{dt}\right]_{00} =$	+0.002 50	+0.002 51	+0.002 5049	+0.002 508 58*
$\left[\frac{dq}{dt}\right]_{00} =$	−0.002 09	−0.002 10	−0.002 0956	−0.002 098 68
$e\left[\frac{d\pi}{dt}\right]_{00} =$	−0.001 84	−0.001 84	. . . . . .	−0.001 844 79
$\left[\frac{dL}{dt}\right]_{00} =$	+0.393 1	. . . .	. . . . . .	+0.393 093 55

PROVISIONAL RESULTS OF LATITUDE MEASUREMENTS AT THE ROYAL OBSERVATORY AT PRAGUE, FROM 1898 NOVEMBER TO 1899 OCTOBER,

Communicated by L. WEINEK.

Date	Observer and No. of Pairs	φ +50° 5′ ″	Monthly Mean
1898 Nov. 3	O 4	16.226	
6	O 9	15.963	
8	S 12	16.102	Nov. 13
17	O 9	15.934	16″.033 (60)
18	S 9, O 8	16.008	
19	S 9	16.074	
Dec. 27	O 8	15.798	
29	O 7	15.700	Dec. 29 15″.810 (70)
31	O 5	15.983	
1899 Jan. 6	S 3, O 3	15.764	
9	O 8	15.906	
14	S 2	15.963	
21	O 9	15.617	Jan. 20 15″.774 (54)
23	S 4	16.030	
26	O 8	15.541	
27	S 8, O 9	15.827	
Feb. 6	O 9, S 6	15.908	
10	S 8, O 8	15.767	
11	S 9, O 1	16.045	
18	O 8	15.976	Feb. 17
21	S 8	16.398	15″.956 (89)
25	S 7, O 3	15.710	
27	O 8, S 8	16.017	
28	S 6	16.062	
Mar. 6	O 16	15.758	
9	O 16	15.554	
11	W 16	15.682	
17	O 16	15.879	Mar. 13 15″.747 (81)
19	O 1	16.050	
20	O 8	15.674	
25	S 8	16.013	

Date	Observer and No. of Pairs	φ +50° 5′ ″	Monthly Mean
1899 Apr. 12	O 17	15.845	
14	O 15	15.638	Apr. 16 15″.655 (49)
23	O 17	15.481	
May 14	O 6	15.551	
17	S 11	15.981	
18	O 17	15.505	May 22
19	S 2	16.248	15″.799 (56)
30	S 17	15.971	
31	O 3	16.019	
June 1	O 17	15.595	
2	S 17	15.896	
4	O 17	15.658	June 4 15″.726 (76)
7	S 17	15.858	
8	O 8	15.505	
July 12	S 3	16.172	July 12 16″.172 (3)
Aug. 9	O 17	15.565	
14	O 4	15.922	Aug. 14
15	O 17	15.823	15″.711 (46)
22	O 8	15.675	
Sept. 30	S 3	15.790	
Oct. 3	S 9	15.878	
10	S 9	15.793	
11	S 9	15.842	Oct. 11 15″.941 (53)
15	S 6	16.672	
16	O 8	15.789	
17	S 9	15.951	

Observers. — W = Prof. Dr. L. Weinek.
S = Adjunct Dr. R. Spitaler.
O = 1st Assistant Dr. E. V. Oppolzer.

Prag, K.K. Sternwarte, 1899 *Oct.* 31.

CONTENTS.

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THE VARIATION OF LATITUDE AT NEW YORK, AND A DETERMINATION OF THE CONSTANT OF ABERRATION, FROM OBSERVATIONS AT THE OBSERVATORY OF COLUMBIA UNIVERSITY,

By JOHN K. REES, HAROLD JACOBY and H. S. DAVIS.

THIRD PAPER.

The observations reduced in this paper were made between January 1898 and December 1899, by Professor JOHN K. REES and Dr. H. S. DAVIS. The latter resigned his position at Columbia University on June 15, 1899, but on account of an illness of Professor REES the observations between June 15 and July 15 were made voluntarily by the other observer. Professor JACOBY has had special charge of the computations, which were made by Miss HARPHAM, assisted by Misses MAGILL, TARBOX and DAVIS.

Again, the Observatory is indebted to Miss C. W. BRUCE for the funds necessary to carry out this work.

The Director of the Observatory, Professor REES, proposes to cease observing in May 1900, when a period of seven years of continuous latitude observing will have been finished.

The observations, including those discussed in our two former papers (*A.J.* 401 and 451), have been divided into four series, as follows:

Series A,	May 1893 to July 1894,	818 pairs	by Rees
		302 "	" Jacoby
		654 "	" Davis
B,	July 1894 to Jan. 1896,	771 "	" Rees
		310 "	" Davis
C,	Jan. 1896 to Jan. 1898,	1065 "	" Rees
		774 "	" Davis
D,	Jan. 1898 to Dec. 1899,	951 "	" Rees
		873 "	" Davis
	Total pairs,	6518	

This table shows the individual observers to have measured:

Rees,	3605 pairs
Jacoby,	302 "
Davis,	2611 "
Total,	6518 pairs

The next table contains mean values of the observed latitude differences as determined from the successive groups, as well as the effect on them of any error in STRUVE's aberration constant. The quantity x is defined by the equation,

$$x = \frac{1}{20.4451} \times \text{(correction required by the constant } 20''.4451)$$

TABLE OF MEAN OBSERVED DIFFERENCES OF LATITUDE.

Series	Group	Diff. of Latitude and Ab. Effect		Weight
A	I–II	$-0''.018$	$+19.2x$	97
	II–III	$+\ .132$	$+11.9$	206
	III–IV	$-\ .038$	$+12.2$	41
	IV–I	-0.111	$+18.9$	53
B	I–II	-0.003	$+19.1$	51
	II–III	$+\ .085$	$+11.6$	62
	III–IV	$+\ .062$	$+11.5$	74
	IV–I	-0.166	$+18.3$	70
C	I–II	$+0.011$	$+19.6$	101
	II–III	$+\ .114$	$+11.6$	104
	III–IV	$+\ .005$	$+11.4$	101
	IV–I	-0.203	$+18.5$	101
D	I–II	$+0.030$	$+18.9$	94
	II–III	$+\ .080$	$+12.0$	106
	III–IV	$+\ .001$	$+10.9$	136
	IV–I	-0.186	$+18.9$	111

From these data the following equations result for the determination of x:

EQUATIONS FOR DETERMINATION OF x.

		Weight	
Series A,	$-0''.035 + 62.2x = 0$	18	$x = +0''.000563$
B,	$-0.022 + 60.5x = 0$	16	$x = +0.000364$
C,	$-0.073 + 61.1x = 0$	26	$x = +0.001195$
D,	$-0.075 + 60.7x = 0$	27	$x = +0.001236$

The solution of these equations gives the following:

VALUES OF THE ABERRATION CONSTANT.

Series A,	20.4566	Weight	18
B,	.4525	"	16
C,	.4695	"	26
D,	.4704	"	27
Mean,	20.4640	"	87

If we take ±0.16 as the probable error of one observation of unit weight, the mean result of our aberration observations down to December 1899 is

Constant of Aberration = ±20″.464 ±0″.006.

The corrections necessary to reduce the declination-systems of the several groups to the mean of all are,

	Series A	Series B	Series C	Series D
Group I	−0.056	−0.064	−0.094	−0.091
II	− .063	− .060	− .061	− .038
III	+ .075	+ .029	+ .068	+ .058
IV	+0.044	+0.095	+0.087	+0.072

In the table below we give the definitive latitudes to be used in continuation of the tables in *A.J.* 401 and 451.

DEFINITIVE LATITUDES.

Series D.

Date	$\varphi = 40° 48' +$	$\varphi - \varphi_0$	Weight
1898 Jan. 10	27.205	−0.124	36
26	27.139	− .190	48
Feb. 10	27.177	− .152	57
Mar. 1	27.246	− .083	98
17	27.169	− .160	27
Apr. 4	27.285	− .044	36
19	27.461	+0.132	24
1898 May 12	27.365	+0.036	78
26	27.429	+ .100	31
June 13	27.501	+ .172	70
26	27.539	+ .210	63
July 12	27.488	+ .159	83
26	27.430	+ .101	26
Aug. 12	27.506	+ .177	35
Sept. 6	27.549	+ .220	50
17	27.295	− .034	32
Oct. 2	27.488	+ .159	48
15	27.490	+ .161	48
Nov. 1	27.485	+ .156	66
15	27.354	+ .025	45
Dec. 1	27.251	− .078	52
14	27.264	− .065	32
1899 Jan. 14	27.138	− .191	39
23	27.291	− .038	48
Feb. 3	27.151	− .178	32
23	27.146	− .183	40
Mar. 13	27.060	− .269	26
26	27.055	− .274	17
Apr. 6	27.189	− .140	32
26	27.366	+ .037	54
May 9	27.275	− .054	33
14	27.194	− .135	43
29	27.267	− .062	68
June 16	27.459	+ .130	11
30	27.275	− .054	52
July 14	27.309	− .020	54
25	27.391	+ .062	24
Aug. 12	27.418	+ .089	57
22	27.458	+ .129	46
Sept. 4	27.322	− .007	69
30	27.397	+ .068	34
Oct. 17	27.451	+ .122	40
Nov. 5	27.361	+ .032	57
24	27.369	+0.040	59
Mean	27.329		

OBSERVATIONS OF THE RELATIVE POSITIONS OF THE INNER SATELLITES OF *SATURN*,

MADE WITH THE 26-INCH REFRACTOR OF THE LEANDER McCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA,

By EVERETT O. EASTWOOD.

The angles here given are each the mean of two comparisons. The distances were obtained from measures of double distances. Corrections have been applied for refraction.

Enceladus–Tethys.

1899	Eastern M.T. (h m s)	p (°)	Eastern M.T. (h m s)	s (″)
May 24	13 18 15	222.31	13 23 19	37.35
	13 32 3	223.31	13 25 49	37.97
	15 24 51	245.10	15 29 37	57.85
	15 36 43	246.40	15 32 42	58.36
June 8	12 27 58	167.90	12 31 18	37.29
	12 36 3	171.00	12 33 36	37.24
23	12 39 28	140.07	12 42 25	46.94
	12 57 21	141.91	12 44 31	47.04
26	12 11 5	307.30	12 16 10	10.49
	12 22 48	306.87	12 19 46	10.42

Enceladus–Dione.

1899	Eastern M.T. (h m s)	p (°)	Eastern M.T. (h m s)	s (″)
May 24	13 0 13	122.51	13 4 33	55.39
	13 14 56	124.17	13 7 55	55.46
	15 12 5	138.57	15 14 52	40.67
	15 19 55	140.98	15 17 13	40.85
June 26	12 28 22	148.79	12 32 13	38.18
	12 38 51	150.58	12 35 8	38.36

Enceladus–Rhea.

1899	Eastern M.T. (h m s)	p (°)	Eastern M.T. (h m s)	s (″)
May 24	13 43 7	271.89	13 46 55	86.76
	13 54 20	271.86	13 49 57	86.68
	15 41 20	275.73	15 46 43	95.86
	15 53 49	276.54	15 50 15	96.13
June 26	12 45 32	62.57	12 51 40	29.83
	13 0 10	62.59	12 55 3	30.24

Tethys–Dione.

1899	Eastern M.T.	p	Eastern M.T.	s
	h m s	°	h m s	″
May 15	12 38 44	72.89	12 48 17	53.79
	12 59 13	74.71	12 54 0	55.05
	13 53 33	77.98	13 59 13	57.63
	14 12 36	29.22	14 2 26	56.29
24	10 49 53	81.18	10 51 18	63.46
	11 5 17	81.96	10 58 51	64.41
	11 57 49	84.98	12 2 19	68.76
	12 8 11	85.62	12 5 22	68.05
	14 0 13	91.58	14 3 41	71.62
	14 10 11	91.88	14 6 9	74.82
25	11 15 38	246.51	11 19 54	71.18
	11 27 40	247.00	11 23 14	71.90
26	10 56 34	35.75	11 1 53	51.08
	11 6 43	37.30	11 2 57	51.04
	11 47 19	44.50	11 49 37	54.72
	11 54 1	45.88	11 51 47	54.91
	13 2 57	55.88	13 6 6	61.74
	13 10 46	57.24	13 8 11	61.91
	13 39 29	60.38	13 42 38	65.06
	13 47 21	61.16	13 44 47	65.10
	14 26 54	65.36	14 30 28	68.87
	14 36 13	66.36	14 32 57	69.62
June 5	12 31 32	233.54	12 35 6	41.20
	12 40 0	234.07	12 37 29	40.99
8	10 21 37	291.27	10 24 41	73.17
	10 29 55	292.25	10 27 16	73.17
	11 12 22	294.50	11 15 21	69.76
	11 20 26	295.28	11 17 54	69.41
	11 51 28	297.86	11 55 13	65.28
	12 0 25	298.64	11 58 0	64.84
19	10 24 40	280.91	10 27 58	101.45
	10 40 11	281.59	10 30 10	101.90
	11 12 46	283.10	11 16 4	100.76
	11 21 50	283.60	11 18 14	99.93
	12 1 13	285.49	12 4 24	97.13
	12 12 53	286.35	12 7 38	96.95
	12 47 4	288.08	12 50 6	93.66
	12 55 31	288.58	12 52 56	93.70
23	12 51 1	76.23	12 53 39	47.17
	12 59 11	77.02	12 56 13	47.79
	13 42 45	78.86	13 47 0	52.59
	13 53 10	80.03	13 50 19	52.16
26	13 4 30	150.46	13 8 47	45.51
	13 14 30	152.24	13 10 15	45.07

Tethys–Rhea.

1899	Eastern M.T.	p	Eastern M.T.	s
May 15	12 12 24	281.99	12 20 11	34.25
	12 31 31	282.11	12 26 5	34.34
	13 30 55	280.11	13 37 9	34.13
	13 46 9	281.33	13 41 7	34.61
24	11 10 59	294.38	11 16 28	77.19
	11 23 46	294.82	11 20 19	76.05
	12 11 9	297.09	12 14 48	71.56
	12 22 54	297.43	12 17 14	71.20
	14 14 38	303.77	14 19 21	58.51
	14 25 29	304.19	14 22 15	59.02
25	11 36 7	316.96	11 42 16	25.57
	11 49 10	317.12	11 44 48	26.13
26	11 11 2	81.43	11 15 43	104.25

Tethys–Rhea. — Cont.

1899	Eastern M.T.	p	Eastern M.T.	s
	h m s		h m s	″
May 26	11 22 19	82.17	11 19 29	104.81
	12 9 25	84.16	12 12 24	108.08
	12 18 2	84.23	12 15 5	108.29
	13 14 1	86.99	13 17 0	113.93
	13 21 47	87.24	13 19 21	114.10
	13 50 29	88.40	13 53 45	116.14
	14 1 0	87.95	13 56 51	116.40
	14 38 34	90.03	14 42 25	118.72
	14 48 54	90.59	14 45 5	119.46
June 5	12 43 21	140.90	12 47 25	72.78
	12 51 14	141.81	12 50 45	72.10
8	10 36 7	37.17	10 40 25	59.26
	10 48 26	38.53	10 41 34	59.94
	11 23 3	43.18	11 27 2	63.97
	11 33 17	45.22	11 29 59	64.59
	12 6 36	48.76	12 9 11	68.08
	12 14 38	49.65	12 11 41	68.86
19	10 43 26	247.79	10 46 52	65.24
	10 53 2	248.93	10 50 20	65.56
	11 25 24	250.47	11 29 40	66.10
	11 35 0	251.19	11 32 4	65.98
	12 15 44	252.96	12 19 53	66.35
	12 25 4	253.12	12 22 26	66.01
	12 57 52	255.40	13 1 24	66.81
	13 6 50	255.64	13 4 21	65.89
23	13 4 53	127.22	13 8 6	25.19
	13 13 9	126.75	13 10 19	24.70
26	13 19 20	78.33	13 24 40	33.58
	13 30 58	78.37	13 27 26	33.68

Dione–Rhea.

1899	Eastern M.T.	p	Eastern M.T.	s
May 15	13 9 19	265.22	13 16 31	89.16
	13 25 23	265.95	13 21 14	88.40
	14 19 1	267.13	14 25 47	92.63
	14 37 21	268.30	14 31 11	93.61
24	11 29 13	280.70	11 32 58	136.56
	11 39 31	280.73	11 35 39	135.99
	12 29 15	282.11	12 34 4	134.41
	12 41 17	282.89	12 37 15	134.49
	14 29 1	286.60	14 32 23	128.31
	14 38 25	286.65	14 35 5	128.30
25	11 56 32	49.91	12 0 36	69.50
	12 10 10	51.20	12 4 22	69.80
26	11 26 12	109.67	11 30 57	74.46
	11 36 33	110.03	11 32 4	73.17
	11 57 31	110.96	11 59 49	71.65
	12 5 5	111.51	11 2 25	71.90
	13 24 9	114.38	13 27 19	65.55
	13 32 9	115.10	13 29 40	65.98
	14 7 39	116.20	14 11 28	62.03
	14 17 41	116.70	14 13 45	63.16
	14 55 48	118.31	15 1 41	59.28
	15 9 51	119.23	15 4 55	58.89
June 5	12 59 15	112.81	13 3 3	85.55
	13 9 53	113.01	13 5 49	85.77
8	10 51 22	80.21	10 55 38	105.59
	11 0 46	80.21	10 57 1	105.70
	11 38 40	81.79	11 44 50	107.04
	11 48 44	82.22	11 45 13	107.24

Dione—Rhea.—Cont.

1899	Eastern M.T.	p	Eastern M.T.	s
	h m s	°	h m s	″
June 8	12 16 33	83.52	12 19 34	107.59
	12 23 56	83.66	12 20 52	107.76
19	10 56 22	139.65	11 0 13	59.13
	11 8 6	141.35	11 3 3	58.05
	11 46 2	144.70	11 48 34	56.21
	11 56 3	145.78	11 52 15	55.99
	12 28 26	149.28	12 31 56	53.93

Dione—Rhea.—Cont.

1899	Eastern M.T.	p	Eastern M.T.	s
	h m s	°	h m s	″
June 19	12 38 10	150.41	12 34 28	54.89
	13 13 14	155.20	13 15 48	52.66
	13 20 36	155.53	13 18 1	53.20
23	13 17 59	227.89	13 24 13	37.78
	13 30 19	228.91	13 26 33	38.00
26	13 36 31	18.32	13 40 30	49.14
	13 46 58	20.41	13 43 21	49.55

OBSERVATIONS OF THE SECOND AND THIRD CONTACTS AT THE SOLAR ECLIPSE OF 1898 JANUARY 22, IN INDIA,

BY W. W. CAMPBELL.

It is well known that the elements of solar eclipses, as published in the standard astronomical annuals, differ very considerably. To illustrate, for the station* near Jeur, India, occupied by the Lick Observatory expedition at the eclipse of 1898 Jan. 22, the computed durations of totality were as follows:

	m	s
American Ephemeris and Nautical Almanac,	1	59
(British) Nautical Almanac,	2	5
Connaissance des Temps,	2	5
Berliner Jahrbuch,	2	16

The programs for photographing the spectrum of the sun's edge have been (thus far) arranged with reference to the instants of second and third contacts. There seems to be little difficulty in predicting the time of second contact, a few seconds in advance, from the magnitude of the uneclipsed crescent of the sun; but the method of predicting the time of third contact, by applying the computed duration to the observed time of second contact, is subject to some uncertainty. Thus, the astronomer in charge of the large expedition located at Viziadrug, India, has stated that his third-contact spectrographic program was seriously affected by the fact that totality was five or six seconds shorter than that predicted by the *British Nautical Almanac.* My own observations fully agree with his as to the length of totality; but no inconvenience arose in the case of our program, since it was based on the 6-second shorter prediction of the *American Ephemeris.* On the other hand, the parties located at Sahdol and Pulzaon, India, observed the duration to be only about one second shorter than that assigned by the *British Nautical Almanac.* It should be noted that the parties near Jeur and Viziadrug were two and four miles, respectively, northwest of the central line indicated by the *British Nautical Almanac*, and that the parties at Sahdol and Pulzaon were four miles southeast of this line. The apparently discordant observations could be harmonized by assuming that the actual central line lay further to the southeast, near or beyond the position assigned to it by the *Jahrbuch*: but the evidence at hand is too meager to warrant a positive statement that such was the case.

I give herewith the results of our observations, in order that observers of future eclipses may take them into account when forming their programs.

The instants of second and third contacts were perfectly definite. The estimates of two observers inside the 40-foot camera watching the 4½-inch image of the sun on the plate-holder, and of several observers outside unassisted by telescopes, all fell within a half second, at the beginning, and at the ending, of totality. The mean of the observed chronometer times of the contacts were,

$$\text{II,}\quad 1^{h}\ 20^{m}\ 38^{s}.5$$
$$\text{III,}\quad 1\ \ 22\ \ 38.3$$

Time was determined by means of sextant double altitudes of the sun, and a chronometer. The observed chronometer corrections, obtained the week of the eclipse, are given below. Each result depends upon two observed double altitudes, one of the upper and one of the lower limb. The sun was observed both east and west of the meridian, at about equal altitudes. It should be said that the chronometer was subjected to an average daily temperature variation, in the shade, of over 40° Fahr.

Local M.T.	ΔT	Local M.T.	ΔT
1898 d h	m s	1898 d h	m s
Jan. 16 20.3	−21 14.1	Jan. 20 20.4	−21 22.2
20.3	14.5	20.4	21.7
17 4.0	16.1	21 4.1	20.3
4.1	17.2	4.2	20.8
19 20.4	22.0	21 20.2	22.5
20.4	20.9	20.3	22.7
20 4.3	20.1	22 4.4	24.3
4.3	−21 20.2	4.4	−21 25.0

* The position of the station was estimated from the "Survey of India" maps, scale 1 inch to the mile, as follows: $L = E\ 75° 9'.5$; $\varphi = +18° 12'.1$; Elevation = 1700 feet. One of the observing stations of the Survey was only four miles from our eclipse camp. The central line of totality indicated by the American, English, French and German Almanacs, was southeast of the camp, at estimated distances of 1¾, 2, 2½ and 3½ miles, respectively.

The correction at the time of the eclipse, Jan. 22ᵈ 1ʰ.0 was assumed to be $-21^m 23^s.7$; whence the local mean times of contacts were,

		d	h	m	s
II,	1898 Jan.	22	0	59	14.8
III,			1	1	14.6
Observed duration,				1	59.8

The local mean times of contacts, as computed from the *American Ephemeris*, were,

		d	h	m	s
II,	1898 Jan.	22	0	59	15.3
III,			1	1	14.2
Computed duration,				1	58.9

The assumed chronometer correction is liable to some uncertainty, — especially on account of the violent changes of temperature; but this uncertainty does not affect the observed duration.

At the eclipse of 1900 May 28, there will no doubt be many observers near the central line who will note the times of contacts, especially of contacts II and III; but these observations will have little or no value in fixing the position of the axis of the eclipse. If there are several observers who propose to confine their programs largely to observations of the contacts, would it not be wise to arrange mutually for the occupation of stations on opposite sides of the central line, a few miles within the boundaries of the shadow?

Lick Observatory, Mt. Hamilton, Cal., 1899 *Dec.* 5.

OBSERVATIONS OF COMETS,

MADE AT THE CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, COLO.,

BY HERBERT A. HOWE.

The following observations of comets were made with the twenty-inch telescope, equipped with a magnifying power of 200 on the Bruce filar-micrometer. The reductions of the stars to apparent place were made by Miss MABEL L. DANIELS. The logarithms of the parallax factors were computed by Miss ELISE C. JONES.

1899 Univer. Park M.T.		*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
				Comet 1898 VIII.					
	h m s			m s	′ ″	h m s	° ′ ″		
June 26	9 40 28	1	20 , 6	+4 4.66	+ 4 49.3	11 29 34.49	+26 5 12.9	9.669	0.590
	9 56 57	2	20 , 8	−0 49.45	+10 55.4	11 29 34.46	+26 5 11.5	9.680	0.612
				Comet a 1899 I.					
June 21	9 18 33	3	20 , 6	−1 50.04	− 3 45.3	14 41 9.39	+28 25 44.3	8.928	0.238
	9 30 53	4	20 , 6	−1 56.10	−13 6.8	14 41 7.44	+28 24 56.0	9.049	0.247
	9 49 21	5	20 , 6	−0 58.15	+ 4 54.1	14 41 5.83	+28 24 27.7	9.182	0.263
26	12 6 20	6	20 , 6	−2 26.84	+ 4 32.7	14 29 9.23	+23 45 50.2	9.629	0.571
	12 29 22	7	28 , 6	+0 2.83	+ 9 17.3	14 29 7.42	+23 45 5.1	9.652	0.599
27	11 20 59	8	20 , 6	+1 36.12	−10 17.2	14 27 26.09	+22 59 41.5	9.572	0.535
	11 38 39	9	19 , 6	+6 5.85	−17 49.5	14 27 24.76	+22 59 7.3	9.599	0.555
29	9 56 34	10	19 , 6	+2 40.06	− 1 19.3	14 24 23.26	+21 32 40.5	9.400	0.486
	10 11 0	11	20 , 6	+1 51.98	− 5 19.5	14 24 22.41	+21 32 13.3	9.442	0.499
July 5	9 26 55	12	20 , 6	+1 56.56	− 6 38.0	14 17 42.64	+17 43 41.8	9.391	0.551
	9 40 3	13	20 , 6	+3 41.80	− 5 38.8	14 17 42.23	+17 43 22.5	9.430	0.559
	9 46 35	14	10 , 3	−3 9.06	− 9 6.2	14 17 42.17	+17 43 9.7	9.448	0.563
6	9 18 10	15	20 , 6	+2 32.48	+ 2 35.0	14 16 55.05	+17 10 27.0	9.377	0.558
	9 27 10	16	20 , 6	−0 58.10	+ 8 59.2	14 16 54.53	+17 10 12.4	9.407	0.563
	9 38 42	17	20 , 6	−2 12.95	− 8 22.5	14 16 54.29	+17 9 55.5	9.438	0.569
	9 50 28	18	20 , 6	−2 51.28	− 8 57.4	14 16 54.01	+17 9 42.8	9.468	0.577
25	9 10 40	19	20 , 6	+2 55.30	− 5 9.7	14 11 50.17	+ 9 21 53.1	9.535	0.680
	9 23 27	20	11 , 5	+3 2.36	+12 17.1	14 11 50.70	+ 9 21 45.0	9.555	0.684
27	8 44 44	21	20 , 6	−6 24.77	− 8 30.6	14 12 2.86	+ 8 45 38.0	9.500	0.679
	9 3 3	22	20 , 6	−6 24.81	− 8 48.7	14 12 2.79	+ 8 45 26.5	9.534	0.685
31	9 13 35	23	20 , 6	+3 47.96	+ 1 25.6	14 12 43.78	+ 7 36 57.8	9.571	0.701
	9 29 40	24	20 , 6	−4 10.75	+ 8 55.4	14 12 43.94	+ 7 36 48.3	9.591	0.705
Aug. 7	8 50 26	25	19 , 6	−2 31.12	+ 9 46.4	14 11 38.90	+ 5 50 42.3	9.573	0.713
	9 3 10	26	20 , 6	−6 16.79	− 5 48.0	14 11 39.19	+ 5 50 35.4	9.589	0.716
8	9 53 25	27	10 , 6	−2 12.75	− 4 57.2	14 15 0.55	+ 5 35 59.7	9.636	0.729
	9 53 25	28	10 , 6	+3 55.53	− 1 51.9	14 15 0.23	+ 5 36 4.8	9.636	0.729
10	8 12 48	29	12 , 6	+3 32.94	− 5 33.7	14 15 42.51	+ 5 9 24.5	9.577	0.718
	8 42 48	30	12 , 6	−5 11.94	− 9 15.6	14 15 42.64	+ 5 9 24.2	9.577	0.718

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	14 25 27.54	+2.29	+26 0 30.9	−7.3	Graham, Cambridge A.G. Catal. 5786
2	14 30 21.60	+2.31	+25 54 23.4	−7.3	" " " " 5804
3	14 42 56.33	+3.10	+28 29 34.0	−4.4	" " " " 6967
4	14 13 0.44	+3.10	+28 38 7.2	−4.4	" " " " 6968
5	14 12 0.88	+3.10	+28 19 38.1	−4.5	" " " " 6963
6	14 31 33.00	+3.07	+23 41 22.9	−5.4	Becker, Berlin A.G. Catal. 5108
7	14 29 1.53	+3.06	+23 35 53.2	−5.4	" " " " 5099
8	14 22 46.94	+3.03	+23 10 4.3	−5.6	" " " " 5082
9	14 21 15.88	+3.03	+23 17 2.4	−5.6	" " " " 5076
10	14 21 40.18	+3.02	+21 34 5.6	−5.8	" " " " 5079
11	14 19 27.41	+3.02	+21 37 38.7	−5.9	" " " " 5064
12	14 12 43.14	+2.94	+17 50 26.2	−6.4	Auwers, Berlin A.G. Catal. 5175
13	14 13 57.48	+2.95	+17 49 7.7	−6.4	" " " " 5181
14	14 20 48.25	+2.98	+17 52 22.0	−6.4	" " " " 5212
15	14 14 19.62	+2.95	+17 7 58.6	−6.6	" " " " 5183
16	14 17 49.66	+2.97	+17 1 19.6	−6.4	" " " " 5195
17	14 19 4.27	+2.97	+17 18 24.3	−6.3	" " " " 5201
18	14 19 42.31	+2.98	+17 18 46.5	−6.3	" " " " 5208
19	14 8 52.08	+2.79	+ 9 27 10.7	−7.9	Glasgow I. 3529
20	14 8 45.55	+2.79	+ 9 9 35.9	−8.0	" 3528
21	14 18 24.82	+2.81	+ 8 54 16.1	−7.5	" 3563
22	14 18 24.79	+2.81	+ 8 54 22.7	−7.5	" 3564
23	14 8 53.10	+2.72	+ 7 35 40.3	−8.1	Glasgow II. 1203
24	14 17 21.92	+2.77	+ 7 28 0.7	−7.8	Munich I, 10089
25	14 17 10.31	+2.71	+ 5 41 4.4	−8.2	Glasgow I, 3559
26	14 20 53.25	+2.73	+ 5 56 31.3	−7.9	" 3571
27	14 17 10.60	+2.70	+ 5 41 5.0	−8.1	Munich I, 10080
28	14 11 2.04	+2.66	+ 5 38 5.2	−8.5	Schjellerup, 5076
29	14 12 6.94	+2.63	+ 5 15 6.6	−8.4	" 5085
30	14 20 51.90	+2.68	+ 5 18 47.7	−7.9	" 5125

NOTES.

June 21. Good central condensation.

June 26. Comet 1898 VIII very difficult.

July 25. Comet very much fainter than on July 6. Nucleus of 13^M.

July 27 and 31. Comet extremely faint.

Aug. 7. Nucleus of $13^M.5$. Observations very difficult on account of "heat lightning."

Aug. 8. Nucleus just visible in terrestrial haze; no nebulosity seen.

Aug. 10. Comet seemed brighter than on Aug. 8. On both nights the comet was connected by direct micometer measures with a faint star near, which was afterward connected with the catalogue star.

THE PERIOD OF PROF. BARNARD'S VARIABLE IN *AQUARIUS*,

S.DM. 4°5381, R.A. $21^h\ 3^m\ 22^s.7$, Decl. −4° 37′.4 (1855),

By J. A. PARKHURST.

An account of the discovery of this variable was given by Prof. Barnard in *A.J.* 456, together with the Harvard photographic measures since 1890. The maximum of the past summer permitted of a good determination, and, in connection with the Harvard measures, gives a good value for the period. After my observations ending 1899 Jan. 14, which are given in Prof. Barnard's note in *A.J.* 456, I looked for the star in March, April and May, finding it invisible; limit about 12^M. It was found at $11^M.5$ June 10, and then rose steadily to a maximum, $9^M.5$, Aug. 16, and fell to $12^M.5$ at my last observation, Oct. 21. I have eighteen observations between the above dates. When the light curve thus found is applied to the observed magnitudes of the previous maximum, the mean interval comes out 209 days, giving a first approximation to the period. To correct this I first used the maximum which is best determined by the Harvard measures, that covered by the six plates from 1893 Aug. 1 to Oct. 31. Taking the highest observed point, 1893 Oct. 7, as the time of maximum (epoch 10 referred to my maximum of 1899 Aug. 16), the resulting period is 213.9 days. On comparing the list of Harvard measures with this period, the agreement was

found surprisingly good, the average residual from the normal curve being $0^{M}.09$, the largest with exceptions noted being $0^{M}.27$.

The normal curve from the Harvard measures was as follows:

Time fr. Max.	Magnitudes Before	After	Time fr. Max.	Magnitudes Before	After
0^{d}	10.28	. .	50^{d}	11.12	11.30
10	10.37	10.47	60	11.10	11.60
20	10.50	10.60	70	11.72	11.83
30	10.68	10.80	80	12.03	
40	10.88	11.02			

Three of the Harvard measures are not in good agreement with the curve; two of them, dated 1893 July 20 and 1898 Oct. 25, with residuals $+0^{M}.57$ and $+1^{M}.00$ respectively, being marked ?, and one, 1891 Nov. 2, residual $+0^{M}.70$, remaining without explanation. With regard to the latter it may be stated that the preceding and following measured magnitudes have residuals $-0^{M}.08$ and $-0^{M}.18$, so that a change in the assumed period would not improve the agreement.

From the data at hand I therefore deduce the following elements of maximum:

1899 Aug. 16 (241 4883) +214 E. Mag. 9.5, visual, 10.3 phot.

I cannot find that the observations can be represented by the period of 150 days, quoted from Prof. PICKERING in *A.J.* 456. There are three maxima fairly well determined by the Harvard measures: 1893 Oct. (6 obs.), 1896 Aug. (4 obs.) and 1897 Nov. (4 obs.). These three and the visually observed maximum of 1899 Jan. are fairly well represented by the elements 1899 Feb. 13 (241 4699) +150 E, but these elements are contradicted by the following measures:

Epoch	Predicted Max.	Observations Date	Mag.
−21	1890 June 30	June 27	<11.8
−18	1891 Sept. 23	Sept. 2	<10.8
		Oct. 2	<10.8
−12	1894 Mar. 11	May 21	10.54
−11	1894 Aug. 9		
		Sept. 5	<11.6
		6	<12.1
− 1	1898 Sept. 16	9	<11.6
		13	<10.8
		29	<10.9

Marengo, Ill., 1899 *Nov.* 23.

DUPLICITY OF τ *TAURI*,

$\alpha = 4^{h}\ 36^{m}$, $\delta = +22°\ 46'$,

BY G. W. HOUGH.

On Oct. 21, 1899, the emersion of τ *Tauri* was observed at position-angle 334°.

It reappeared as a 9^{M} star, and after an interval of rather more than one second, it flashed out in full brightness.

From this observation I infer that the star is a close double.

I examined the star on one good night with the 18½-inch refractor, but failed to see the companion.

Owing to the closeness and inequality of the components it may now be beyond the reach of any telescope.

From the motion of the moon I derive the following: p = n.p., $s = 0''.15$ to $0''.4$, mag. (4.4 − 9). If the position-angle of the companion is, as I imagine, near 360°, no abnormal phenomena would be noticed during an occultation except for an emersion, occurring between 300° and 360° position-angle.

Dearborn Observatory, Northwestern University.

OBSERVATIONS OF TEMPEL'S SECOND COMET = c 1899.

BY R. G. AITKEN.

1899 Mt. Hamilton M.T.		$*$	No. Comp.	☌ − $*$ $\Delta\alpha$	$\Delta\delta$	☌'s apparent α	δ	log $p\Delta$ for α	for δ
	h m s			s	′ ″	h m s	° ′ ″		
Aug. 10	11 12 9	1	10 , 10	−16.94	+0 52.5	21 5 1.73	−29 16 29.4	n8.914	0.906
11	11 55 17	2	10 , 8	+ 9.83	+1 15.2	21 6 17.26	−29 43 35.2	8.431	0.910
18	11 29 13	3	12 , 8	+ 2.18	+2 23.0	21 15 0.09	−32 24 18.7	8.000	0.920
25	10 42 6	4	10 , 10	−13.48	+2 33.6	21 24 0.43	−34 22 3.9	n8.808	0.921
27	10 58 58	6	10 , 8	+ 5.48	−0 59.8	21 26 39.97	−34 47 57.6	n7.778	0.924
Sept. 1	9 43 34	7	10 , 10	+18.44	−3 27.1	21 33 19.42	−35 36 29.4	n9.211	0.919
4	9 23 18	9	15 , 9	+40.84	+6 9.4	21 37 24.11	−35 55 59.9	n9.286	0.916
4	9 51 38	10	8 , 8	+ 3.78	−2 1.6	. . . .	. . . .	. .	. .
7	10 50 29	11	10 , 10	− 1.69	−3 31.4	21 41 38.58	−36 8 40.5	8.352	0.927
8	10 16 10	12	10 , 8	−12.49	−5 10.7	21 43 0.69	−36 11 6.5	n8.565	0.927
26	10 20 9	14	10 , 10	+ 9.32	+2 51.7	22 9 10.26	−35 10 28.0	8.929	0.923

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 5 13.69	+4.98	−29 17 41.2	+19.7	Gould's Zones XXI: 117
2	21 6 2.44	+4.99	−29 45 10.1	+19.7	Tucker, L.O. Meridian Circle, Sept. 1899
3	21 14 52.77	+5.14	−32 27 1.8	+20.1	Gould's Zones XXI: 426
4	21 24 38.72	+5.19	−34 24 57.6	+20.1	Micrometer comparison with (5)
5	21 25 15.72	+5.19	−34 20 2.4	+20.1	Gould's Zones XXI: 742
6	21 26 29.28	+5.21	−34 47 17.8	+20.0	$\frac{1}{3}$ (2 Cord. G.C. 29492 + 1 G.Z. XXI: 780)
7	21 32 55.73	+5.25	−35 33 22.5	+20.2	Micrometer connection with (8)
8	21 33 13.11	+5.25	−35 27 35.7	+20.2	Gould's Zones XXI: 980
9	21 36 38.05	+5.25	−36 2 29.3	+20.0	$\frac{1}{4}$ (3 Cord. G.C. 29698 + 1 G.Z. XXI: 1089)
10	21 37 16.00	. .	−35 54 0.0	. .	Cordoba D.M. −36°14953. 9.5 mag.
11	21 41 38.05	+5.22	−36 5 29.1	+20.0	$\frac{1}{3}$ (2 Cord. G.C. 29791 + 1 G.Z. XXI: 1247)
12	21 43 7.97	+5.21	−36 6 15.8	+20.0	Gould's Zones XXI: 1307
13	22 7 58.57	+5.06	−35 15 34.2	+20.1	" " XXII: 196
14	22 8 55.88	+5.06	−35 13 39.8	+20.1	Micrometer comparison with (13)

The observations of August 11, 18, 27 and September 8, were made with the 36-inch, the others with the 12-inch equatorial. In every case the measures of $\Delta\alpha$ were made directly with the micrometer. In August and early in September the comet nucleus was very sharp, and the comet bright — easily visible in a 3½-inch telescope. On Sept 26. it was faint enough to be difficult with the 12-inch refractor. Several of the catalogue stars used are not very well determined. the catalogue position depending on a single observation.

Lick Observatory, University of California, 1899 *Dec.* 5.

OBSERVATIONS OF LEONIDS AT THE LICK OBSERVATORY IN 1899,

By JAMES E. KEELER.

As stormy or cloudy weather prevailed on Mt. Hamilton, during the entire period of apparition of the Leonids, the plan which had been made for photographic and other observations could not be carried out. On Nov. 13, at 16^h, the clouds suddenly cleared away, and a watch was kept until dawn. Ten Leonids were counted in one hour. On Nov. 15, between 12^h and dawn, the sky was occasionally visible through rifts in the fog which surrounded the mountain. A few meteors, apparently Leonids, were seen, but it was evident that no considerable shower was in progress.

From these few observations, and from reports which have been received from more favored places on the western coast, it would seem that the Leonids were not more numerous in 1899 than in ordinary years.

OBSERVATIONS OF LEONIDS,

By M. W. WHITNEY.

The Leonids were observed at Vassar College Observatory on November 13th, 15th and 16th, from midnight to dawn, by various students in the department of Astronomy. Tuesday night was cloudy throughout, and on Wednesday the sky was observed at intervals for two hours and a half. Even when clear, the air was heavy with moisture. On Monday twenty-five Leonids were recorded, and of these twenty were seen after the moon set. On Wednesday twenty-seven were seen, the percentage exceeding that of Monday. On Thursday thirty-seven were recorded. A good many meteors, not Leonids, were noted, and several of these were plainly Geminids.

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THE METHODS OF REDUCTION AND PUBLICATION OF MEASURES OF CELESTIAL PHOTOGRAPHS OF ISOLATED STAR GROUPS: WITH A NEW REDUCTION OF THE RUTHERFURD *PRAESEPE* PLATES.

By ARTHUR R. HINKS.

§1. Introduction.

It will be best to state at the outset my object in writing this note. I have been occupied recently in preparing to undertake the work with the new photographic equatorial of the Cambridge Observatory, which the Director proposes to devote to determination of stellar parallax, measures of star clusters, etc. A study of the many methods, differing widely in principle as well as in detail, which have been used by various workers, seems to me to show that everything points to the advisability of adopting a method based upon that devised for the work of the Astrographic Catalogue by Professor Turner. He has given an example of such an application of his methods in his discussion of some measures of the *Pleiades* group made at Oxford (*Monthly Notices, R.A.S.*, 1894, Vol. LIV, p. 489). If, however, full advantage is to be taken of the admirable simplicity of this method, it follows that the final results are presented in a form differing greatly from the form in which such work has hitherto been published, and a doubt arises whether this might be some impediment to future comparison with the work of other observers. The object of this paper is to present for comparison an example of the application of such methods to a set of measures of photographic plates already reduced and published on the old lines.

§2. General Explanation of the Principles of the Reduction.

In his various papers in the *Monthly Notices* Professor Turner has developed the idea that in the treatment of photographic results we must avoid as far as possible the use of the old spherical coordinates, right ascension and declination, and carry out almost the whole of our work in the rectangular coordinates in which measures on the plate are most naturally and conveniently made. The resulting simplification in the reductions depends upon the fact that all the necessary corrections to the measured coordinates, with insignificant exceptions, can be expressed as linear functions of the measured coordinates themselves. The total corrections to be applied to the position of a star whose coordinates upon the plate are x, y, can therefore be written

$$\Delta x = ax + by + c$$
$$\Delta y = dx + ey + f$$

And when these six constants a, b, c, d, e, f are determined, the measures upon the plate can be immediately reduced to the values they would have upon an ideal plate of the desired centering, orientation and scale-value, and free from the disturbing effects of refraction, aberration, precession, and nutation.

If we have to determine these constants we require the meridian places of as many as possible of the stars which are found upon the plate. These meridian places, reduced to our standard epoch, are immediately converted by simple transformation formulas into the rectangular coordinates which they would have upon the ideal plate as defined above. If these "standard" coordinates of any known star be ξ, η, we have

$$\xi = x + ax + by + c$$
$$\eta = y + dx + ey + f$$

Each known star gives us a similar pair of equations; and by solution of the two sets of equations we obtain the values of the constants.

If our work is catalogue-work, two courses are now open. We may apply to each measure the linear correction, and reduce all our measured to standard coordinates. We may further apply to each the transformation to meridian coordinates, and obtain the right-ascension and declination of every star on our plates at the standard epoch.

We may, on the other hand, publish our measures for each plate as they come from the measuring machine, uncorrected for anything save the errors of the machine and the *réseau*; and with them the values of the six constants which will reduce them to standard coordinates, and thence if we so desire, to meridian coordinates.

By a comparatively recent decision of the permanent committee the latter far simpler course has been adopted for the work of the astrographic chart. The publication of the raw measures, with the necessary constants of reduction, is accepted as sufficient even in catalogue-work, from which a certain number of meridian places will eventually be required.

The measurement of isolated objects such as star clusters and stars suspected of parallax, is a branch of celestial photography distinct from cataloguing, and unfettered by the ultimate requirement of meridian places; and here the principles summarized above may receive an extension as simple as it is valuable.

Suppose that we are considering two plates of a star cluster taken at any epochs, and under conditions subject only to the limitations that the zenith-distances at the time of exposure were not excessive, and that the centering of the cluster on the plates was approximately the same. Since the expression for the reduction of each plate to "standard" coordinates is a linear function of the measured coordinates, the expression for the direct reduction of one plate to the other is also a linear function of these coordinates. If $x_1\,y_1$, $x_2\,y_2$ be the measures of the same star on the two plates, we may write

$$x_2 = x_1 + ax_1 + by_1 + c$$
$$y_2 = y_1 + dx_1 + ey_1 + f$$

Every star which occurs on both plates affords a similar pair of equations; and by the solution of the two sets of simultaneous equations we obtain a strong determination of the constants by means of which the two plates may be directly compared for the detection of proper motion or parallax.

The best test of the accuracy of this simple procedure is to apply it to a series of measures already reduced by other methods. I am fortunate in finding in Dr. Frank Schlesinger's *measurement and reduction of the Rutherfurd photographs of the Praesepe group* (*contributions from the Observatory of Columbia University*, No. 15) a series most suitable for the purpose.

Dr. Schlesinger has followed closely the method of reduction developed by Professor Harold Jacoby. The measures are first freed from the effects of refraction by means of formulas expressed in rectangular coordinates. A comparison between the calculated and measured positions of five known stars upon the plate furnishes the constants of the linear expressions for the sums of the remaining corrections. The results for each star are corrected and tabulated*. Corrections for proper motion are then applied; means are taken; and the transformation corrections applied to form a final catalogue of right-ascensions and declinations.

§3. New Reduction of the Rutherfurd *Praesepe* Plates.

I propose to compare directly plates I, II, III, V, VII, VIII, IX, with plate IV. (For details of these plates *c. op. cit.* pp. 190 *et seq.*) The choice of the latter was made, and the work well under way, before it was noticed that the error of orientation of this plate is considerably greater than that of the others. Two of the constants of reduction will therefore be unusually large, which will put the method to a somewhat severe test.

There are thirty-two stars common to the eight plates. The "center of gravity" of these is near the point (+3.3 −3.0); and for convenience the origin of coordinates was shifted to this point. The measured coordinates, subject to this change of origin, were from Dr. Schlesinger's memoir, which gives the mean measures corrected only for the errors of the machine. A series of equations is formed of the type

$$ax_1 + by_1 + c + x_1 - x_2 = 0$$
$$dx_1 + ey_1 + f + y_1 - y_2 = 0$$

It is here convenient to note that a great deal of trouble is saved if, instead of finding the constants to reduce each plate to plate IV, we perform the inverse operation, and reduce plate IV to each of the others. The seven series of equations differ then only in their numerical terms.

In this way seven series of equations were formed, each containing two sets of thirty-two equations. Prof. Turner has given (*M. N.* 1895, Vol. LV, p. 115) a very simple approximate method of solving such a set, due to Mr. Dyson, as follows:

If we take the mean of all the equations in which the coefficient of a is negative, and the mean of all in which it

* These quantities are in columns headed "right-ascension" and "declination," which they are not. They are referred to in the text (p. 248) as "projected right-ascension and declination," which is equally misleading, since they are really hybrid quantities. The so-called "right-ascensions" are the x-coordinates multiplied by a constant which is the value of 1 mm. in seconds of arc at center of plate secant (declination of center of plate) and added to the right-ascension of the central star. They are therefore quantities of the form $\theta + m \tan \phi \sec \delta$. Similarly the so-called "declinations" are quantities of the form $\theta + m \tan \phi$.

It is necessary to protest once more against this misuse of the terms "right-ascension" and "declination" which continues to disfigure the photographic work of the Columbia College Observatory, although the error was repeatedly pointed out by Mr. Dyson and Professor Turner during the controversy which arose concerning Professor Jacoby's refraction-formulas.

is positive, we obtain two equations in which the coefficients of b are small, and the coefficients of a large and of opposite sign. The coefficients of c are identical. Subtracting one from the other, we have an equation in a and b, with a large coefficient for a and a small one for b.

Similarly, by dividing the equations with regard to the signs of the coefficients of b, we obtain an equation in a and b having a small coefficient for a and a large one for b.

The solution of the pair of equations gives a weighty determination of a and b. And the value of c is found by substituting in the four mean equations, which provides a check on the accuracy of the arithmetic.

In order to test the value of this method, I have obtained for each set of thirty-two equations the simple approximate solution, and also the rigid least-square solution.

The resulting values of the constants are given in the following tables.

Table I. Values of the Constants from the Least-Square Solutions.

	a	b	c	P.E. of one x-equation	d	e	f	P.E of one y-equation
IV to I	+.000261 ±.0000145	+.000448 ±.0000126	+.00010 ±.000251	±.00144	−.000175 ±.0000118	+.000178 ±.0000103	−.00064 ±.000208	±.00118
IV to II	+.000119 ±.0000215	+.000609 ±.0000187	−.00124 ±.000378	.00214	−.000413 ±.0000143	+.000066 ±.0000124	+.00070 ±.000251	.00142
IV to III	+.000188 ±.0000183	+.001113 ±.0000159	−.00063 ±.000322	.00182	−.000811 ±.0000112	+.000108 ±.0000097	−.00296 ±.000197	.00111
IV to V	+.000077 ±.0000186	+.001386 ±.0000162	−.00271 ±.000327	.00185	−.001096 ±.0000118	+.000022 ±.0000103	−.00438 ±.000208	.00118
IV to VII	−.000058 ±.0000196	+.001517 ±.0000171	−.00555 ±.000345	.00195	−.001344 ±.0000130	−.000053 ±.0000113	−.00351 ±.000229	.00130
IV to VIII	−.000107 ±.0000201	+.001231 ±.0000175	−.00521 ±.000354	.00200	−.001146 ±.0000113	−.000087 ±.0000098	−.00396 ±.000199	.00112
IV to IX	−.000021 ±.0000282	+.001813 ±.0000245	−.00478 ±.000496	±.00281	−.001609 ±.0000170	−.000069 ±.0000147	−.00354 ±.000298	±.00169

Table II. Values of the Constants from the Approximate Solution.

	a	b	c	P.E. of one x-equation	d	e	f	P.E. of one y-equation
IV to I	+.000298	+.000437	+.00010	±.00152	−.000175	+.000179	−.00064	±.00118
IV to II	+.000147	+.000593	−.00124	.00216	−.000412	+.000055	+.00070	.00143
IV to III	+.000180	+.001111	−.00063	.00181	−.000838	+.000106	−.00295	.00111
IV to V	+.000084	+.001361	−.00270	.00190	−.001088	+.000013	−.00438	.00120
IV to VII	−.000056	+.001490	−.00555	.00203	−.001341	−.000071	−.00349	.00132
IV to VIII	−.000076	+.001204	−.00521	.00206	−.001143	−.000092	−.00395	.00113
IV to IX	+.000028	+.001770	−.00477	±.00290	−.001588	−.000089	−.00353	±.00171

The quantities in Table II headed "P.E. of one equation" have been formed in the same way as the corresponding quantities in Table I, from the equation

$$e = 0.6745\sqrt{\frac{[vv]}{32-3}}$$

The process we have followed, of finding the constants to reduce Plate IV to each of the other plates, effects a great economy of labor in the solution of the equations. But what we actually want to do is to reduce each plate to Plate IV; and the constants required to do this differ slightly from those found above.

If

$$x_2 = x_1 + ax_1 + by_1 + c$$
$$y_2 = y_1 + dx_1 + ey_1 + f$$

it is easily seen that, to a sufficient degree of approximation,

$$x_1 = x_2 - (a - a^2 - bd)\,x_2 - (b - ab - be)\,y_2 - (c - ac - bf)$$
$$y_1 = y_2 - (d - ad - ed)\,x_2 - (e - bd - e^2)\,y_2 - (f - cd - ef)$$

To effect the inverse operation we must therefore add to our constants the following small corrections, and then change all their signs.

Table III. Corrections to be Added to the Constants of Tables I and II.

	a	b	c	d	e	f
IV to I	$+10^{-6}\times 0$	$10^{-6}\times 0$	$+10^{-5}\times 0$	$10^{-6}\times 0$	$+10^{-6}\times 0$	$-10^{-5}\times 0$
II	0	0	0	0	0	0
III	1	0	0	0	1	0
V	2	0	1	0	1	0
VII	2	0	1	0	2	1
VIII	1	0	0	0	1	1
IX	3	0	1	0	3	1

With these modified constants all the plates were reduced to plate IV. The results were collected and the means taken separately for the groups at the two epochs 1870.3 and 1877.3. These were combined into a final mean for 1875.0 with weights inversely proportional to the distances from this epoch. This procedure is precisely equivalent to that adopted by Dr. Schlesinger, but has a certain formal advantage in that it does not represent the discordances between the means of the two groups as entirely due to proper motion.

The results are given in the following table. The means of the reduced measures are still in the original units; but the probable errors have been expressed in seconds of arc, that their size may be more readily appreciated.

Table IV. Mean Results from the Eight Plates.

Star	x-Coordinates					y-Coordinates				
	I. Least-Sq. Solution	II. Appr. Solution	P.E. of I	P.E. of II	Schlesinger P.E.	I. Least-Sq. Solution	II. Appr. Solution	P.E. of I	P.E. of II	Schlesinger P.E.
	mm	mm	"	"	"	mm	mm	"	"	"
1	−37.8084	.8072	±.034	±.037	±.041	+18.6760	.6763	±.016	±.019	±.026
2	36.7998	.7992	.017	.022	.018	− 0.4231	.4229	.014	.014	.015
3	35.6810	.6807	.031	.039	.032	−15.0107	.0107	.012	.013	.021
4	33.9154	.9157	.026	.031	.024	−32.0909	.0910	.015	.011	.010
5	24.9201	.9190	.036	.037	.022	+31.9447	.9451	.016	.016	.015
6	20.7284	.7278	.017	.013	.031	+17.1992	.1995	.018	.017	.031
7	17.9726	.9726	.017	.017	.025	−16.0434	.0435	.026	.026	.024
7A	13.8869	.8867	. .	. .	. .	− 0.7700	.7700	. .	. .	. .
8	13.8897	.8891	.028	.027	.028	+17.9468	.9469	.019	.019	.022
10	12.9793	.9791	.035	.035	.028	− 4.0211	.0211	.008	.008	.012
11	12.1187	.1187	.027	.025	.032	− 9.7577	.7578	.018	.017	.027
14	3.5110	.5104	.014	.013	.031	+23.9393	.9396	.014	.015	.022
15	3.3002	.3001	.015	.015	.022	+ 2.9996	.9996	.014	.014	.012
16	2.3683	.3690	.027	.028	.028	−31.2375	.2378	.009	.008	.021
17	− 0.9658	.9661	.026	.027	.035	−13.1485	.1486	.007	.007	.011
18	+ 0.5751	.5751	.021	.021	.024	−12.3011	.3013	.016	.017	.019
19	0.5815	.5820	. .	. .	. .	+28.8897	.8900	. .	. .	. .
20	0.9227	.9224	.018	.016	.016	−13.0784	.0786	.018	.018	.023
22	2.8448	.8452	.027	.027	.040	+18.6740	.6742	.015	.013	.015
23	4.2164	.2166	.037	.037	.044	+16.1987	.1988	.016	.016	.025
23A	5.2367	.2369	.016	.016	.024	+17.7859	.7860	.019	.017	.022
24	6.3634	.3630	.044	.042	.051	−13.6624	.6626	.013	.013	.016
25	6.9372	.9370	.035	.033	.043	− 3.1238	.1239	.013	.013	.016
26	7.0646	.0639	.023	.023	.034	−26.1059	.1062	.016	.014	.028
27	7.3093	.3091	.025	.025	.037	− 4.2591	.2592	.016	.015	.022
28	7.5374	.5374	.016	.016	.030	+ 6.9751	.9751	.017	.017	.020
29	8.1098	.1103	.027	.025	.046	+30.5955	.5958	.017	.018	.030
31	8.7319	.7315	.038	.037	.041	−12.7587	.7589	.021	.020	.027
32	10.6276	.6266	.020	.023	.026	−36.5866	.5870	.014	.011	.028
33	12.2785	.2775	.034	.038	.048	−34.2559	.2563	.024	.021	.037
34	12.9025	.9023	.027	.028	.029	− 0.8359	.8360	.016	.017	.012
35	14.8789	.8794	.020	.023	.028	+36.4325	.4328	.017	.019	.025
36	16.3688	.3688	.021	.024	.028	+13.8806	.8807	.017	.019	.022
37	16.5233	.5228	.018	.018	.032	−10.2453	.2455	.020	.020	.029
38	20.1315	.1312	.033	.036	.031	+ 6.7647	.7646	.019	.018	.030
39	20.8706	.8706	.011	.010	.027	+13.0650	.0650	.012	.011	.021
40	22.7285	.7274	.023	.029	.020	−31.8969	.8973	.022	.024	.014
43	30.5936	.5933	.023	.025	.036	+ 9.9457	.9457	.025	.026	.035
44	31.1251	.1252	.036	.039	.027	+29.3695	.3696	.022	.023	.013
45	+35.4483	.4473	±.022	±.027	±.032	−21.4897	.4902	±.015	±.018	±.022

The x-measures do not come out as well as the y-measures, as was to be expected from the fact that the star discs are sensibly elongated owing to defective clock driving. I do not think, however, that this is responsible for the whole of the inferiority of the x-results. A reference to Tables I and II shows that the constants derived from the approximate solution frequently differ from those of the least-square solution by considerably more than the probable error of the latter. Yet, judging by the probable errors of one equation for each solution, they represent the equations very nearly as well. To a smaller extent this is true of the y-equations also.

A suspicion arises that the measures, especially the x-measures, may be in part affected by some systematic error; and it is well to examine the method of measurement used.

In Tables I and II of Dr. Schlesinger's memoir full details of this work are given. The stars have been divided into two portions, differing somewhat for different plates; and the two portions are referred to the central star by series of measurements made on different days. Care was taken to include one or two other stars, as well as the central star, in both portions. But it is clear that in the result one portion of stars may be displaced systematically with respect to the other portion by an amount depending on the actual errors made in bisecting the two or three common stars on the different days.

In order to examine whether such a systematic error actually exists, I have divided the residuals in the least-square solution into two portions, corresponding to the portions in which the stars were measured, and excluding these stars common to the two. The results are given in Table V.

Table V. Classification of Residuals.

Plate	I	II	III	IV	V	VII	VIII	IX
Mean x-residual								
Portion I	−.0004	+.0010	−.0007	.0000	−.0001	+.0005	+.0002	−.0006
II	+.0004	−.0008	+.0008	−.0001	+.0001	−.0010	+.0001	+.0005
Mean y-residual								
Portion I	−.0002	+.0001	+.0001	.0000	+.0002	+.0002	.0000	−.0004
II	+.0002	−.0003	−.0001	+.0002	−.0002	−.0005	+.0003	+.0004

It seems clear from this table that the x-coordinates of Plates II, III, VII and IX, at least, are affected to some extent by the source of systematic error indicated above.

Objections may be raised to this conclusion on the ground that the stars in the separate portions are not sufficiently well distributed over the plate to make it safe to argue in this manner. But an examination of the probable errors in Table IV shows that the accuracy of the comparison for stars near the edges of the plate is little inferior to that for the central portions. And I cannot escape the conclusion that the greater part of the discrepancy is due to a real defect in the method of measurement adopted.

In view of this apparent inferiority of the x-measures, which was remarked by Dr. Schlesinger, but attributed by him solely to the elongation of the star images, it will be fairer, I think, to confine our attention to the y-measures in discussing the results.

It should be noted that the probable errors of Table V, computed from the residuals from the mean, are unaffected by the reduction to a common epoch. The residuals are precisely the same as the residuals in each group from its separate mean. The probable errors are therefore a criterion of the accuracy with which plates taken at the same epoch can be compared.

The values of the discordances between the mean of the early and the late plates will afford a criterion of the accuracy with which plates taken at different epochs may be compared. I have, therefore, taken from Dr. Schlesinger's collected results (pp. 250 *et seq.*) the differences between the means of the two groups. These differences include the effect of the proper motion of the group as a whole, whereas the differences in my solutions include only the effect of the relative proper motions of the stars in the group. I have therefore subtracted each of the former from the mean discordance of the thirty-two stars on which my solutions depend. Dr. Schlesinger's results, which are given in seconds of arc, have been reduced to the original units on the scale $1^{mm} = 52''.79$. The following table exhibits the discordances with their probable errors.

Table VI. Discordances Between the Means in y of the Two Groups of Plates Separated by an Interval of Seven Years.

Star	Schlesinger		Hinks Least-sq. Solution		Hinks Approx. Solution		Star	Schlesinger		Hinks Least-sq. Solution		Hinks Approx. Solution	
	Disc.	P.E.	Disc.	P.E.	Disc.	P.E.		Disc.	P.E.	Disc.	P.E.	Disc.	P.E.
	mm.		mm.		mm.			mm.		mm.		mm.	
1	+0.0015	±.0009	−0.0003	±.0006	+0.0002	±.0007	23A	.0000	±.0008	0.0007	±.0007	−0.0006	±.0006
2	+ 15	5	+ 6	5	+ 9	5	24	− 8	5	+ 3	5	0	4
3	− 26	8	− 23	5	− 22	5	25	− 8	5	− 3	4	− 5	5
4	− 26	4	− 17	5	− 17	5	26	− 17	11	− 1	6	− 6	5
5	+ 23	5	+ 1	6	+ 6	6	27	+ 15	8	+ 21	6	+ 20	5
6	+ 32	12	+ 18	6	+ 21	6	28	− 8	8	− 8	6	− 8	6
7	− 34	9	− 32	9	− 31	9	29	+ 21	11	+ 8	6	+ 12	6
7A	− 51	−	− 48		− 48	−	31	+ 2	11	+ 12	7	+ 9	7
8	+ 8	8	− 6	7	− 4	7	32	− 17	11	+ 5	5	0	4
10	+ 13	4	+ 11	3	+ 12	3	33	− 15	13	+ 5	8	0	7
11	+ 2	11	+ 4	4	+ 3	3	34	+ 2	4	+ 6	6	+ 6	6
14	+ 9	8	− 4	5	− 1	5	35	+ 13	9	− 1	6	− 1	7
15	+ 8	4	+ 5	5	+ 5	5	36	+ 17	8	+ 11	6	+ 12	6
16	− 19	8	− 3	3	− 6	3	37	− 11	11	− 3	7	− 4	7
17	− 2	4	+ 5	3	+ 3	2	38	− 6	11	− 6	7	− 7	6
18	+ 2	7	+ 14	6	+ 11	6	39	− 8	8	− 7	4	− 8	4
19	− 2	−	− 15	−	− 14	−	40	− 13	5	+ 8	8	+ 3	9
20	− 4	8	+ 1	6	0	6	43	− 17	13	− 13	9	− 14	9
22	+ 9	5	+ 6	6	+ 10	5	44	− 8	5	− 13	8	− 12	8
23	+ 26	±.0009	+0.0019	±.0006	+0.0021	±.0006	45	−0.0004	±.0008	+0.0015	±.0006	+0.0011	±.0007

§4. Comparison of the Three Solutions.

Let us call Dr. Schlesinger's solution, Solution A.
My least-square solution, Solution B.
My approximate solution, Solution C.

We will confine our attention to the y-coordinates, for the reasons given above.

In the first place let us compare solutions B and C. An inspection of the latter half of Table IV shows that there is practically nothing to choose between the two. The scale is $0^{mm}.0001 = 0''.0053$. The differences between the corresponding means seldom amount to $0''.02$, and are well within the probable errors. which are almost identical in the two solutions.

Secondly, in a few cases the probable errors of solutions B and C come out slightly larger than those of solution A, but in most they are smaller. It follows that the plates in each group agree among themselves better in B and C than in A.

Finally, if we examine the discordances between the early and late plates. as shown in Table VI. we see that a few large ones, which may fairly be attributed to real proper motion, agree well on the whole in the three solutions. The remainder, which are doubtless due in the main to accidental irregularities in the plates and in their measurement, are in general considerably smaller in solutions B and C than in A; and their probable errors, being functions of the probable errors of Table IV, are smaller also.

It appears to me then that the solutions B and C have certain advantages over solution A, in that they are apparently more accurate and certainly far less laborious.

As for accuracy, they produce a closer agreement between the plates for any one epoch, and presumably a better mean determination of the star-places at that epoch. They also allow of a more exact comparison between the results of groups of plates taken at different epochs, for the determination of parallax and proper motion.

As for the labor, solution B is much shorter than A; and C involves about one-quarter of the labor of B, and is apparently just as accurate.

For parallax-work there seem to be great advantages in the methods B and C of this paper. For the presentation of measures of star clusters they have at present this disadvantage, that the older work is published in a form not quite immediately comparable with the new. It should not be forgotten, however, that the comparison of two pieces of old work requires reductions for precession, and almost always systematic corrections for the errors of such value and orientation which result from imperfect meridian places of the stars of reference.

It is one of the strongest points of the new method that no meridian places are required in the comparison of the plates. Nor in fact are they required at all, except that in the deduction of parallaxes we want an approximate knowledge of the right-ascension and declination of the center of our plate.

For the detection of proper motion by comparison with future photographic work, the final results in my Table IV are more immediately available than if they had been expressed in right-ascension and declination.

§ 5. Conclusion.

I should sum up as follows what seem to me to be the conclusions to be drawn from this paper.

Determinations from photographs of parallax, and of positions of the stars in a cluster, may be carried out with advantage entirely in rectangular coordinates, and the results published in them.

The approximate method of solution of the equations of condition may safely be adopted.

The saving of labor is so great that a just proportion is established between the work of taking the measures of the plates, and the deduction of the results from them.

Let me, in conclusion, make it quite clear that I can claim no particular originality for the methods used in this paper. They are simply an obvious adaptation of the ideas developed by Professor Turner. I do not think, however, that it has been generally recognized how far-reaching his methods are, and I can only hope that no injustice has been done to them in the example here brought forward.

We are passing through the critical period of transition from visual to photographic methods, and it matters greatly how to lay out a sound line of advance. May I ask of more experienced workers their opinion of the way which seems to me a good one.

The Observatory, Cambridge, England, 1899 Oct. 28.

THE LIGHT-CURVE OF CERASKI'S *ALGOL*-VARIABLE +DM. 45°3062.

By J. A. PARKHURST.

I have 45 observations of this star between 1899 June 15 and Sept. 12. Of these, 22 fall within $0^d.20$ of the time of minimum, computed from the date given by Prof. Ceraski in *A.N.* No. 3572; assuming the minimum of 1899 May $7^d.454$ as the zero epoch, and using the period $4^d\ 13^h\ 44^m$. The 22 observations relate to the following minimum:

E	Comp. Min. Gr. M.T.	No. of Obs.	E	Comp. Min. Gr. M.T.	No. of Obs.
	d h			d h	
11	June 26 17.9	8	23	Aug. 20 11.7	2
13	July 5 21.4	2	25	29 18.2	1
14	10 11.1	2	28	Sept. 12 11.1	2
16	19 14.6	5			

The magnitudes given depend on a provisional scale, the main points of which are,

		M
a	DM. +45°3055	8.6
f	3067	9.2
d	3063	9.6
q	5*s* foll. 1'.8 S. of *d*	12.0

On this scale the normal light is $8^M.75$, and the minimum $11^M.4$. The following points will show the character of the curve drawn through the 22 observed magnitudes:

Time	Magnitudes Before Min.	After Min.
d		
0.00	11.40	. .
0.05	10.84	11.10
0.10	10.10	10.80
0.15	9.54	9.80
0.20	9.10	9.15

The observed magnitudes were in fair agreement with this curve, the average residual being $\pm 0^M.08$.

The minimum by this curve is at $+0^d.02$, giving a correction of $+0^h.5$ which may be applied to the minimum of epoch 19, about the mean of the times. By the data given by Prof. Ceraski this minimum was due Aug. $2^d\ 7^h.8$, which with the above correction becomes $2^d\ 8^h.3$. The elements given by Prof. E. C. Pickering in Harvard College Observatory Circular No. 44, yield for this epoch (No. 771) Aug. $2^d\ 8^h\ 12^m$. My observations therefore tend to confirm Prof. Pickering's extension of the period to $4^d\ 13^h\ 45^m\ 2^s$.

OBSERVATIONS OF PLANET *EY* (*Charlois, Dec. 4*),

MADE AT THE SCHOOL OF SCIENCE OBSERVATORY, PRINCETON, N.J.,

By TAYLOR REED.

1899 Greenwich M.T.	*	No. Comp.	Planet — * $\Delta\alpha$	Planet — * $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Dec. 8 16 55 51	1	3 , 4	−5 17.55	+1 41.3	4 33 49.47	+14 28 13.2	9.067	9.639
9 15 5 39	2	2	. . . .	−6 25.5	. . . .	+14 31 31.6	. . .	9.645
15 32 19	2	3	−2 53.59	. . . .	4 32 55.35	. . . .	n9.178	. .
12 16 10 23	3	6 , 6	+1 27.87	−3 37.9	4 30 8.67	+14 12 23.9	8.640	9.636

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	4 39 1.31	+5.707	+14 26 22.4	+ 9.53	Yarnall 2065
2	4 35 13.23	+5.714	+14 37 47.2	+ 9.93	Yarnall 2042
3	4 28 35.09	+5.715	+14 45 51.1	+10.66	W. Bessel 541

OBSERVATIONS OF NEW VARIABLES,

BY J. A. PARKHURST.

ANDERSON'S NEW VARIABLE IN *Hercules*.

This was announced in *A.N.* No. 3594 as $9^M.0$, 1899 Aug. 22 and 24, and $9^M.9$ Sept. 21. I have ten observations between Oct. 12 and Nov. 20. The star faded from about $11\frac{1}{4}^M$ at the first comparison to $12\frac{1}{4}^M$ Nov. 4, and was not seen (limit about 12^M) Nov. 8, 15 and 20. Its variability seems therefore to be well established. It is $0^s.8$ preceding and 2′ 2″ north of the star DM. +19°3489, which is No. 6537 in the Berlin Astron. Gesell. Catalogue. The position of the variable is therefore

R.A.	Decl.	
h m s	° ′ ″	
17 53 27.7	+19 29 41	(1855)
55 24.7	29 20	(1900)

ANDERSON'S NEW VARIABLE IN *Cygnus*.

The discoverer found (*A.N.* No. 3594) a decline from $8^M.5$, 1899 Aug. 28, to $9^M.2$ Sept. 20. From nine observations between Oct. 12 and Nov. 20 I have found a decline from $9^M.3$ to $9^M.9$, based on the two comparison-stars whose coordinates from the variable and assumed magnitudes are as follows:

	R.A.	Decl.	Mag.	
	s	″		
b	+6.0	+33	9.4	30°3965
d	+7.7	−26	9.9	

The position of the variable, from micrometer comparisons with the two Bonn VI stars DM. +30°3962 and 3965, is

R.A.	Decl.	
h m s	° ′ ″	
20 9 44.4	30 37 54	(1855)
11 32.6	46 1	(1900)

CERASKI'S VARIABLE IN *Cepheus*.

This star was announced in *A.N.* No. 3512 and my first observations were given in *A.J.* No. 457. Since it went below my limit ($12^M.8$) in November 1898 I looked for it once or twice a month. It was below my limit up to and including 1899 Aug. 30, but at the next observation, Sept. 26, it had reappeared and was only $\frac{1}{2}^M$ fainter than +82°635 (?) The change since that time has not been enough to determine a maximum. As it was now bright enough to measure with precision, I took the opportunity to correct the position given in *A.J.* 457, having obtained the places of the comparison-stars by the kindness of Dr. FRANK SCHLESINGER. The DM. numbers of these stars are uncertain, being obtained by counts from the nearest known stars on the charts. The positions are from CARRINGTON'S Catalogue.

	Car.	DM.	R.A.	Decl.	
			h m s	° ′ ″	
b	3222	+32°635	21 6 59.5	+82 25 5.7	(1855)
a	3225	636	8 22.7	24 28.9	(1855)
Δ *Vb*			23.1	3 51.4	
Δ *Va*			1 49.6	4 24.3	
Place of *V*			21 6 39.2	82 28 58.1	(1855)
			3 38.5	39 50.3	(1900)

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NOTES ON VARIABLE STARS. — No. 31,

BY HENRY M. PARKHURST.

Y Scorpii. Period probably fifteen days either more or less than a year. My observations indicated a misidentification of the variable by Dr. PETERS. I therefore repeated the reduction, assuming the preceding star to be the variable.

Minima. In comparing with elements, the minima will be assumed midway between the maxima, whenever a more exact $M-m$ is not given in the Third Catalogue.

RESULTS OF OBSERVATIONS.

No.	Star	Phase	Observed Date Julian	Calendar	E	Corr.	W	Mag.	Factors			Remarks
				1899							d	
5338	*U Bootis*	Min.	4854	July 18	40	+95	8	12.4	0.88	1.01	59	Max. from elements, July 18
"	"	Min.	4853	July 17	40	+94	6p	12.4	–	–	–	
"	"	Min.	4853.8	July 17	40	+94	9	12.24	0.98	0.95	32	Comb. obsns. July 1 to Aug 15
5105	*RT Librae*	Max.	4799	May 24	–	–	7	8.37	0.86	0.75	22	250?
5438	*Y Librae*	Max.	4819	June 13	51	– 2	9	9.04	0.75	0.62	19	
5494	*S Librae*	Min.	4809	June 3	48	– 8	6	11.8	–	–	–	
5501	*S Serpentis*	Max.	4852	July 16	71	+34	9	8.93	0.97	1.73	27	
"	"	Max.	4857	July 21	71	+39	4r	8.5	–	–	–	
"	"	Max.	4865	July 29	–	+47	5r	8.5	–	–	–	Includes last observation
5511	*RS Librae*	Min.	4817	June 11	17	–19	7	11.95	1.10	2.46	45	
5566	*RU Librae*	Max.	4000	Mar. 16	10	–	E	–	–	–	–	1897
"	"	Min.	4480	July 9	12	–	E	–	–	–	–	1898
"	"	Min.	4800	May 25	13	–	E	–	–	–	–	1899
"	"	Max.	4960	Nov. 1	13	–	E	–	–	–	–	
5677	*R Serpentis*	Max.	4910.5	Sept. 12	74	+ 2	9	7.16	0.89	0.72	13	
5688	*R Librae*	Max.	4827	June 21	–	–	9	9.10	1.06	1.00	26	Last interval 730 days
5770	*R Herculis*	Max.	4816	June 10	39	–29	9	8.49	0.58	0.65	22	Correction stationary
5795	*W Scorpii*	Max.	4811	June 5	38	–37	7	11.27	–	–	–	Confirms negative correction
5798	*RU Herculis*	Min.	4570	Oct. 7	–	–	1	–	–	–	–	
"	"	Max.	4839	July 3	–	–	1r	–		–	–	Probably earlier
5830	*R Scorpii*	Max.	4810	June 5	59	–26	1	10.6	–	–	–	
5831	*S Scorpii*	Max.	4780	May 5	128	–	E	10.1	–	–	–	Probably later
5903	*Y Scorpii*	Max.	4831	June 25	–	–	8	11.0	1.16	1.50	30	See note above
5950	*W Herculis*	Max.	4801	May 26	26	–22	7	8.45	0.92	1.00	37	Correction steadily increasing
6132	*R Ophiuchi*	Max.	4926.6	Sept. 28	51	–18	9	7.13	0.54	0.41	12	
6160	*RT Herculis*	Min.	4882	Aug. 15	4	–	E	13]	–	–	–	Period suggested *A.J.* 421
6207	*Z Ophiuchi*	Min.	4881	Aug. 14	7	+20	5	12.5	2.34	2.77	85	No observations in August
6225	*RS Herculis*	Max A	4868.3	Aug. 1			8	8.34	1.17	1.18	34	Per. 219, from Yendell's obsns.
"	"	Max B	4902.9	Sept. 4	–	–	9	7.97	0.99	1.01	25	221, from Yendell's obsns.
"	"	Max B	4895	Aug. 28	–	–	3r	7.9	–	–	–	
6624	*T Serpentis*	Max.	4912	Sept. 14	41	–29	9	9.82	2.19	1.66	30	
6849	*R Aquilae*	Min.	4822	June 16	17	+28	1	10.6	–	–	–	Lowest observation
6894	*S Lyrae*	Max.	4840.0	July 4	5	+29	9	9.94	1.26	1.85	32	Per. 438.2 ; max. *A.J.* 365

Individual Observations.

Including Observations by Arthur C. Perry.

5338 *U Bootis.*

(Continued from 444.)

Julian	Calendar	Mag.
	1899	
4818.6	June 12	10.79_2
4825.6	19	10.74_2
4832.6	26	10.41_2
4837.7	July 1	11.7P
4838.6	2	11.48_2
4838.6	2	11.7P
4844.6	8	12.1P
4867.6	31	11.54_2
4867.6	31	11.9P
4873.6	Aug. 6	11.1P
4882.6	15	10.82_2
4894.5	27	10.26_2
4897.5	30	10.4P
4905.5	Sept. 7	10.33_2
4920.5	22	10.32_2

5405 *RT Librae.*

(Continued from 444.)

Julian	Calendar	Mag.
	1899	
4775.6	Apr. 30	8.8
4784.6	May 9	8.6
4786.6	11	8.87_2
4789.6	14	8.60_2
4800.6	25	7.99_2
4801.6	26	8.58_2
4805.6	30	8.72_2
4805.6	30	11.2P
4814.6	June 8	8.98_2
4835.6	29	10.2

5438 *Y Librae.*

(Cont. from 388. Comp. Stars 333)

Julian	Calendar	Mag.
	1899	
4757.6	Apr. 12	11.7]
4773.6	28	11.8]
4784.6	May 9	11.8
4787.6	12	11.25_2
4806.6	31	9.60_2
4812.6	June 6	9.06_2
4816.6	10	9.08_2
4820.6	14	8.89_2
4824.6	18	9.03_2
4827.6	21	9.8_2
4833.6	27	9.77_2

5494 *S Librae.*

(Continued from 415.)

Julian	Calendar	Mag.
	1899	
4787.7	May 12	10.4
4789.6	14	10.54_2
4808.6	June 2	12.15_2
4814.6	8	12.18_2
4835.6	29	10.68_2
4838.6	July 2	10.72_2

5501 *S Serpentis.*

(Cont. from 444. Comp. Stars 388)

Julian	Calendar	Mag.
	1899	
4757.6	Apr. 12	11.6:
4773.6	28	11.1
4773.6	28	11.04_2

5501 *S Serpentis* — Cont.

Julian	Calendar	Mag.
	1899	
4779.6	May 4	10.95_2
4801.6	26	11.66_2
4812.6	June 6	12.16_2
4820.6	14	11.92_2
4835.6	29	9.85_2
4837.7	July 1	9.8P
4839.6	3	9.7P
4840.6	4	8.90_2
4847.6	11	8.90_2
4854.6	18	8.88_2
4862.6	26	9.11_2
4865.6	29	9.06_2
4867.6	31	8.5P
4873.5	Aug. 6	9.13_2
4875.5	8	9.0P
4897.5	30	9.7P

RS Librae.

(Cont. from 444. Comp. Stars 388)

Julian	Calendar	Mag.
	1899	
4789.6	May 14	10.54_2
4808.6	June 2	11.97_2
4814.6	8	12.09_2
4835.6	29	11.59_2
4838.6	July 2	11.93_2
4850.6	14	11.41_2

5566 *RU Librae.*

Julian	Calendar	Mag.
	1897	
4074.7	May 29	10.4
4094.6	June 18	11.0:
4096.6	20	12.0]
	1898	
4458.6	June 17	12]
	1899	
4775.6	Apr. 30	10]
4805.6	May 30	12]
4846.6	July 10	10.2
4847.6	11	10.53_2
4867.6	31	9.94_2
4874.5	Aug. 7	9.82_2
4894.5	27	9.32_2

5677 *R Serpentis.*

(Continued from 365.)

Julian	Calendar	Mag.
	1899	
4757.6	Apr. 12	11.7:
4773.6	28	12.6]
4787.6	May 12	12.6]
4805.6	30	12.4
4817.6	June 11	11.8]
4835.6	29	12.9
4846.6	July 10	12.27_2
4866.6	30	9.52_2
4867.5	31	9.83_2
4874.5	Aug. 7	8.70_2
4882.6	15	7.83_2
4883.6	16	8.78_2
4892.5	25	8.19_2
4894.5	27	7.84_2
4902.5	Sept. 4	7.35_2
4905.5	7	7.24_2

5677 *R Serpentis* — Cont.

Julian	Calendar	Mag.
	1899	
4908.5	Sept. 10	7.23_2
4911.5	13	6.96_2
4914.5	16	7.27_2
4918.5	20	7.58_2
4920.5	22	7.56_2

5688 *R Librae.*

(Continued from 421.)

Julian	Calendar	Mag.
	1898	
4458.6	June 17	12.5]
4481.6	July 10	13]
	1899	
4805.6	May 30	10.62_2
4806.6	31	10.70_2
4806.6	31	10.79_2
4808.6	June 2	11.20_6
4810.6	4	10.80_2
4812.6	6	10.40_4
4816.6	10	10.26_2
4832.6	26	10.3
4833.6	27	9.77_2
4836.6	30	10.14_2
4839.6	July 3	10.88_2
4845.6	9	10.71_2
4866.6	30	11.7

5770 *R Herculis.*

(Continued from 456.)

Julian	Calendar	Mag.
	1899	
4757.6	Apr. 12	11]
4773.6	28	11.7
4773.6	28	11.29_2
4779.6	May 4	10.98_2
4798.6	23	10.34_2
4808.6	June 2	8.89_2
4814.6	8	7.77_2
4818.6	12	8.65_2
4822.6	16	8.92_2
4825.6	19	8.80_2
4829.6	23	8.85_2
4838.6	July 2	8.64_2
4846.6	10	9.08_2
4866.6	30	9.81_2

5795 *W Scorpii.*

(Continued from 421.)

Julian	Calendar	Mag.
	1899	
4805.6	May 30	11.3
4806.6	31	11.29_2
4808.6	June 2	11.14_2
4810.6	4	11.55_2
4812.6	6	10.94_2
4816.6	10	11.62_2
4832.6	26	11.6]
4833.6	June 27	11.8
4840.6	July 4	12.0]
4850.6	14	12.0]

5798 *RU Herculis.*

Julian	Calendar	Mag.
	1898	
4487	July 16	12]P
4507.6	Aug. 5	12]P
4547.6	Sept. 14	12]P

5798 *RU Hercul.* — Cont.

Julian	Calendar	Mag.
	1898	
4570.5	Oct. 10	12]P
4597.5	Nov. 3	12]P
	1899	
4839.6	July 3	8.4P
4855.6	19	9.1
4858.6	22	8.74_2
4862.6	26	9.08_2
4865.6	29	9.29_2:
4867.6	31	9.1P
4873.6	Aug. 6	9.1P
4875.5	8	9.03_2
4883.6	16	9.24_2
4889.5	22	9.30_2
4897.5	30	9.60_2
4897.5	30	9.5P

5830 *R Scorpii.*

(Continued from 431.)

Julian	Calendar	Mag.
	1899	
4787.7	May 12	10.7
4806.6	31	10.6
4808.6	June 2	10.73_2
4810.6	4	10.63_2
4816.6	10	10.94_2
4832.6	26	10.96
4833.6	27	11.36_2
4836 6	30	11.61_2

5831 *S Scorpii.*

(Continued from 456.)

Julian	Calendar	Mag.
	1899	
4787.7	May 12	10.5
4806.6	31	10.1
4808.6	June 2	10.51_2
4810.6	4	10.59_2
4816.6	10	10.34_2
4832.6	26	10.26
4833.6	27	11.25_2
4836.6	30	11.54_2

5903 *Y Scorpii.*

Julian	Calendar	Mag.
	1899	
4810.6	June 4	11.1
4816.6	10	11.55_2
4832.6	26	11.2
4833.6	27	10.71
4836.6	30	11.07_2
4839.6	July 3	11.63
4845.6	9	10.95
4866.6	30	11.7

5950 *W Herculis.*

(Continued from 421.)

Julian	Calendar	Mag.
	1899	
4770.6	Apr. 25	10.7:
4774.6	29	9.55_2
4785.6	May 10	9.43_2
4801.6	26	8.27_2
4806.6	31	8.49_2
4812.6	June 6	8.81_2
4822.6	16	9.25_2

6132 *R Ophiuchi.*

(Continued from 456.)

Julian	Calendar	Mag.
	1899	
4805.6	May 30	11.5]
4817.6	June 11	11.5
4837.6	July 1	11.2
4838.6	2	11.00_2
4850.6	14	10.01_2
4866.6	30	10.2
4874.5	Aug. 7	9.38_2
4882.6	15	8.63_2
4883.6	16	8.43_2
4892.5	25	8.20_2
4901.5	Sept. 3	7.07
4902.5	7	7.88_2
4905.5	7	8.02_2
4908.5	10	7.84_2
4915.5	17	7.23_2
4919.5	21	7.35_2
4920.5	22	7.86_2
4925.5	27	6.85_2
4926.5	28	7.00_2
4929.5	Oct. 1	7.07_2
4933.5	5	8.20_2
4940.5	12	7.63_2

6160 *RT Herculis.*

(Continued from 456.)

Julian	Calendar	Mag.
	1899	
4757.6	Apr. 12 to	
4905.5	Sept. 7	13]
	5 dates	
4837.7	July 1 to	
4905.6	Sept. 7	12]P

6207 *Z Ophiuchi.*

(Cont. from 456 Comp. Stars 333)

Julian	Calendar	Mag.
	1899	
4775.6	Apr. 30	10.8
4785.6	May 10	10.1
4787.6	12	9.81_2
4808.6	June 2	10.39_2
4814.6	8	10.34_2
4835.6	29	11.52_2
4847.6	July 11	11.98_2
4867.6	31	12.34_2
4905.5	Sept. 7	12.32_2
4920.5	22	12.00_2

6225 *RS Herculis.*

(Continued from 456.)

Julian	Calendar	Mag.
	1899	
4787.7	May 12	10.7
4816.6	June 10	11.1]
4832.6	26	10.2
4837.6	July 1	9.92_2
4837.7	1	9.9P
4844.6	8	9.3P
4846.6	10	9.30_2
4865.6	29	7.93_2:
4867.6	31	8.6P
4873.6	Aug. 8	8.5P
4875.5	8	8.71_2

6225 *RS Hercul.* — Cont.

Julian	Calendar 1899	Mag.
4883.6	Aug. 16	8.97$_2$
4889.5	22	8.55$_2$
4897.5	30	7.91$_2$
4997.6	30	7.9P
4904.5	Sept. 6	7.94
4905.6	7	8.1P
4908.5	10	8.22$_2$
4914.5	16	8.17$_2$
4919.5	21	8.55$_2$

6624 *T Serpentis.*

Continued from 456.

Julian	Calendar 1899	Mag.
4805.6	May 30 to	
4837.6	July 1	12.5]
	3 dates	
4847.6	11	12.1
4866.6	30	10.0
4875.6	Aug. 8	10.19$_2$
4882.6	15	10.22$_2$
4891.6	27	9.88$_2$

6624 *T Serpentis* — Cont.

Julian	Calendar 1899	Mag.
4897.6	Aug. 30	9.4P
4905.6	Sept. 7	9.2P
4907.5	9	9.82$_2$
4912.5	14	9.81$_2$
4918.5	20	9.76$_2$
4925.5	27	9.92$_2$
4929.5	Oct. 1	10.35$_2$
4933.5	5	10.55$_2$
4942.5	14	10.39$_2$

6849 *R Aquilae.*

Continued from 456.

Julian	Calendar 1899	Mag.
4822.6	June 16	10.59$_2$
4847.6	July 11	10.51$_2$
4868.6	Aug. 1	9.97$_2$

6894 *S Lyrae.*

Cont. from 456. Comp. Stars 330.

Julian	Calendar 1899	Mag.
4801.7	May 26	11.3

6894 *S Lyrae* — Cont.

Julian	Calendar 1899	Mag.
4814.6	June 8	10.91
4822.6	16	10.34$_2$
4827.6	21	10.22$_2$
4835.6	29	9.83$_2$
4839.6	July 3	9.83$_2$
4845.6	9	10.07$_2$
4868.6	Aug. 1	10.45$_2$
4873.6	6	10.58$_2$

COMPARISON STARS, 1893–1899.

5677 *R Serpentis.*

Star	DM.	Mag.	n
F	+15°2925	7.07	34
I	+15°2923	6.92	37
N	+15°2921	8.32	32
1*R*	+16°2837	7.87	2
T	+15°2916	8.44	2
1*T*	+15°2919	8.60	19
2*T*	+15°2922	9.38	18
1*a*	7*n* *N*	10.21	4
1*b*	7*s*12*f* 2*T*	10.12	9

5688 *R Librae.*

Star	DM.	Mag.	n
U	−15°4211	9.03	9
1*U*	−15°4215	9.65	6
W	−15°4212	9.59	17
2*X*	−16°4170	11	0
d	4*n*1*p* *W*	10.56	32
e	2*n*1*f* *d*	11.28	12
f	3*n*2*p* *U*	11.22	12
g	2*s*1*p* *U*	11.16	6
h	2*n*1*p* *U*	11.75	1

5770 *R Herculis.*

Star	DM.	Mag.	n
T	+18°3113	9.00	21
1*T*	+18°3114	9.15	8
2*T*	+18°3119	9.75	1
U	+18°3121	9.61	37
1*U*	+18°3120	9.51	31
Y	+18°3115	10.42	9
Z	+18°3116	10.76	5
1*Z*	+18°3118	10.29	5
d	1*n*3*f* 1*Z*	11.70	4

6132 *R Ophiuchi.*

Star	DM.	Mag.	n
E	−16°4436	7.28	20
F	−16°4434	7.27	25
I	−16°4426	8.67	23
1*I*	−15°4466	8.16	27
S	−16°4416	9.39	4
W	−15°4453	10.15	7
X	−16°4415	10.18	5
Y	−16°4418	9.97	2
i	4*s* *U*	11.54	2

OBSERVATIONS OF COMETS AND MINOR PLANETS,

MADE AT THE VASSAR COLLEGE OBSERVATORY,

BY MARY W. WHITNEY AND CAROLINE E. FURNESS.

1899 Greenwich M.T.	⁎	No. Comp.	Planet — ⁎ Δα	Planet — ⁎ Δδ	Planet's Apparent α	Planet's Apparent δ	log pΔ for α	log pΔ for δ	Obs.
			COMET *a* 1899 I						
June 26 16ʰ 4ᵐ 25ˢ	1	6	−1ᵐ 12ˢ.05	−5′ 22″.2	14ʰ 29ᵐ 23ˢ.91	+23° 52′ 7″.1	9.532	0.539	W
27 15 8 0	2	5	+4 50.39	−4 7.3	14 27 40.36	+23 5 51.4	9.407	0.503	W
			(107) [1895 CC].						
Oct. 5 14 50 35	3	6	+0 36.23	−0 16.4	23 13 51.78	+ 7 17 9.1	*n*8.602	0.696	W
6 14 19 31	3	7	−0 2.56	−5 11.1	23 13 12.98	+ 7 12 14.5	*n*8.959	0.699	W
12 14 18 4	4	8	+0 21.17	+0 54.5	23 9 41.39	+ 6 42 53.1	*n*8.620	0.703	W
			(362) [1893 *R*].						
Nov. 2 15 1 39	5	6	−0 47.01	+1 9.8	1 19 49.77	+ 8 52 44.8	*n*8.688	0.678	W
4 15 56 43	6	9	−0 30.53	−0 47.9	1 18 6.92	+ 8 50 6.9	8.886	0.680	W
6 14 18 14	6	6	−2 3.27	−3 1.2	1 16 34.19	+ 8 47 53.7	*n*8.982	0.681	W
			(198) *Ampella.*						
Nov. 6 16 17 27	7	6	−0 55.97	−1 4.7	3 5 0.49	+29 26 15.2	*n*8.928	0.277	W
8 15 40 15	8	7	+0 32.38	+2 43.7	3 3 2.82	+29 8 13.7	*n*9.149	0.336	W
9 13 31 24	8	7	−0 22.13	−5 56.4	3 2 8.32	+28 59 33.7	*n*9.571	0.471	W
29 12 18 34	9	7	−1 47.13	+1 8.7	2 45 32.18	+25 31 39.3	*n*9.514	0.500	W
			(31) *Euphrosyne.*						
Nov. 4 18 9 45	10	6	−2 19.50	+3 43.8	2 44 20.78	+27 11 3.1	9.264	0.380	F
6 15 37 27	11	6	+1 15.86	+5 29.7	2 41 50.94	+27 22 23.3	*n*9.076	0.351	F
7 15 0 7	12	6	−0 16.27	−1 1.9	2 40 31.52	+27 28 0.5	*n*9.268	0.373	F
8 13 35 34	13	6	+0 41.10	−2 17.6	2 39 19.94	+27 33 20.9	*n*9.521	0.464	F
10 13 28 1	14	8	+0 58.57	+6 51.3	2 36 44.94	+27 44 2.2	*n*9.515	0.456	F
21 12 11 23	15	7	−0 38.38	−4 12.5	2 22 46.55	+28 32 12.1	*n*9.558	0.469	F
24 14 4 34	16	7	+0 17.76	−1 8.7	2 19 10.84	+28 43 29.7	*n*9.077	0.310	F

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	14 30 32.89	+3.07	+23 57 34.6	− 5.3	Becker, Berlin A.G. Catalogue 5105
2	14 22 46.94	+3.03	+23 10 4.3	− 5.6	" " " " 5082
3	23 13 11.10	+4.45	+ 7 16 55.2	+30.3	Bruns & Peter, Leipzig A.G. Catalogue 11596
4	23 9 15.49	+4.43	+ 6 41 28.0	+30.6	" " " " " 11571
5	1 20 31.96	+4.82	+ 8 51 6.3	+28.7	" " " " " " 522
6	1 18 32.62	+4.83	+ 8 50 26.2	+28.6	" " " " " " 508
7	3 5 50.71	+5.75	+29 26 59.6	+20.3	Graham, Cambridge, E. A.G. Catalogue 1598
8	3 2 24.68	+5.76	+29 5 9.0	+21.0	" " " " 1580
9	2 47 13.65	+5.66	+25 30 6.6	+24.0	" " " " 1493
10	2 47 4.71	+5.57	+27 6 57.0	+22.3	" " " " 1492
11	2 40 29.49	+5.59	+27 16 30.4	+23.2	" " " " 1439
12	2 41 15.18	+5.61	+27 31 39.1	+23.3	" " " " 1446
13	2 38 33.22	+5.62	+27 35 14.8	+23.7	" " " " 1425
14	2 35 37.75	+5.62	+27 36 46.6	+24.3	" " " " 1414
15	2 23 19.27	+5.66	+28 36 58.1	+26.5	" " " " 1337
16	2 18 47.44	+5.64	+28 47 11.1	+27.3	" " " " 1292

Observations of Comet *a* and (407) were made with a square-bar occulting micrometer. The remaining observations were made with the filar micrometer.

OBSERVATIONS OF VARIABLE STARS, — No. 8,

By WM. E. SPERRA.

103. *T Andromedae*.

Fourteen observations of this star, between 1899 June 27 and August 26, give as the date of maximum 1899 July 28.5, at $8^M.8$. The star was of $8^M.7$ at beginning, and $9^M.0$ at ending of observations. The decline in brightness was quite rapid for a week after maximum.

2815. *U Geminorum*.

These observations are the results of my continued watch of this star, the last of the series having been published in *A.J.* 399. The magnitudes conform to those of the DM. For obvious reasons no attempt is made to give the date of maximum.

		M			M
1897 March	5.59	9.2	1897 March	7.60	9.3
	6.52	8.8		10.52	9.6

1897 August 17.88 $9^M.6$

		M			M
1897 Nov.	23.97	9.8	1897 Nov.	27.97	9.9
1898 Feb.	6.51	9.7	1898 Feb.	10.61	9.3
	7.49	9.2		13.37	9.6

1899 February 27.52 $9^M.6$

		M			M
1899 May	4.58	11.5>	1899 May	6.58	9.7
	8.58	11.5>			
1899 Dec.	30.54	11.0>	1900 Jan.	1.51	9.4<
	31.59	9.3		3.61	10.2

3407. *S Antliae*.

1899 Dec. 19; nine observations from $19^h 41^m$ to $23^h 38^m$, yield as the time of minimum $21^h 27^m$ Gr. M.T.

7792. *SS Cygni*.

The following are my observations of this star for the season of 1899. As in the case of *U Geminorum* the variation of this star is so rapid, and the weather so uncertain, that it is nearly impossible to get a single set of observations that will give a good date of maximum, and it becomes necessary to combine the results of several observers, and for this reason I give my individual observations.

For the identification of the comparison-stars used I give the coordinates from the variable, the position of which for 1900 is R.A $21^h 38^m 46^s.2$, Decl. $+43° 7' 35''$.

	s	′	M		s	′	M
g	−30.7	− 2.4	11.42	*a*	−21.3	− 1.0	9.54
l	+19.5	+ 6.4	11.06	*c*	+ 0.3	+ 8.0	9.30
o	+10±	+13.7	10.62	*s*	+60	+28	8.90
f	+48±	−13.5	10.25	*b*	+27.0	− 0.2	8.49
n	−29.3	+13±	9.99	*r*	–	–	8.18

1899 Apr. 19 to June 30, 11 observations at normal light.

	M		M
1899 June 30.60	11.26	1899 July 6.62	8.72
July 1.60	10.64	8.59	8.78
1.82	9.82	9.63	9.00
2.60	8.63	10.63	9.81
3.60	8.36	12.59	10.52
4.75	8.38		

1899 August 6 to August 18, six observations at normal light.

	M		M
1899 Aug. 22.55	8.57	1899 Aug. 30.62	8.45
26.34	8.38	Sept. 2.57	8.69
27.86	8.57	6.54	9.73
28.56	8.38	7.55	10.40
29.56	8.38	9.59	10.84

1899 Oct. 29.54	8.73 M	1899 Nov.	1.52	9.70 M
			6.58	normal
1899 Dec. 1.55	8.78 M	1899 Dec.	6.58	10.34 M
1899 Dec. 30.55	11.00> M	1900 Jan.	4.53	8.38 M
1900 Jan. 1.48	8.78		6.48	8.50
3.56	8.63		7.58	8.60

8598. *U Pegasi.*

1899 Dec. 21: six observations from 12h 5m to 15h 5m give as the time of minimum 13h 25m Gr. M.T.

Randolph, Ohio, 1900 January 15.

OBSERVATIONS OF TEMPEL'S SECOND COMET = *c* 1899,

MADE AT THE CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, COLO.,

BY HERBERT A. HOWE.

The following observations were made with the twenty-inch telescope, equipped with a magnifying power of 200 on the Bruce filar-micrometer. The reductions of the stars to apparent place were made by Miss MABEL L. DANIELS. The logarithms of the parallax factors were computed by Miss ELISE C. JONES. On Aug. 7 the comet had a nucleus of mag. 9. In November measures were difficult, because of the comet's faintness.

1899 Univer. Park M.T.		⋆	No. Comp.	☄ — ⋆ Δα	☄ — ⋆ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Aug. 7	13 5 47	1	20 , 8	+0 29.89	+ 9 37.3	21 1 25.58	−27 54 6.6	9.192	0.901
	13 18 43	2	20 , 6	−4 48.19	+ 5 45.6	21 1 26.03	−27 54 21.0	9.262	0.898
8	12 16 48	3	20 , 8	−0 47.15	+ 9 1.8	21 2 35.73	−28 21 35.5	8.739	0.910
	12 29 43	4	18 , 6	−3 46.66	− 3 7.2	21 2 36.33	−28 21 49.2	8.922	0.908
10	12 37 45	5	19 , 6	+1 17.70	− 3 25.1	21 5 2.46	−29 16 50.9	9.058	0.909
	12 47 9	6	20 , 8	+0 29.88	−23 16.9	21 5 2.95	−29 17 1.1	9.130	0.907
17	12 10 5	7	20 , 6	+3 34.96	+10 15.7	21 13 42.04	−32 3 28.0	8.989	0.918
	12 22 7	8	20 , 6	−4 58.23	− 9 14.1	21 13 43.14	−32 3 37.2	9.097	0.916
24	11 22 35	9	20 , 6	−5 47.77	+ 7 18.5	21 22 40.68	−34 7 34.9	8.495	0.926
	11 47 58	10	20 , 6	+5 54.40	− 2 12.7	21 22 41.76	−34 7 48.0	8.962	0.923
25	11 4 29	11	20 , 6	−2 11.78	+ 1 24.5	21 23 58.56	−34 21 37.2	n7.753	0.926
	11 18 58	12	20 , 6	+3 7.84	− 1 16.9	21 23 59.10	−34 21 46.6	8.462	0.926
26	11 22 23	13	20 , 6	−1 16.57	+11 49.6	21 25 17.94	−34 35 8.7	8.639	0.926
	11 34 55	14	20 , 6	−3 53.37	+10 58.4	21 25 18.90	−34 35 12.1	8.866	0.925
Sept. 4	11 17 42	15	20 , 6	+2 9.06	+ 6 4.2	21 37 26.22	−35 56 13.1	8.951	0.927
	11 29 31	16	20 , 8	+0 43.62	+ 5 55.4	21 37 26.89	−35 56 14.4	9.071	0.925
5	11 20 7	17	16 , 8	+0 10.43	+ 3 8.9	21 38 49.21	−36 1 5.3	9.007	0.926
	11 36 18	18	20 , 6	−2 53.07	+ 3 58.8	21 38 50.18	−36 1 10.4	9.146	0.923
9	11 25 52	19	15 , 6	+2 11.79	+ 5 8.5	21 44 25.03	−36 13 0.0	9.147	0.924
	11 43 42	20	20 , 6	−3 13.41	+ 5 6.9	21 44 25.90	−36 13 1.1	9.259	0.920
25	10 38 46	21	20 , 6	+2 2.14	+ 7 19.6	22 7 38.08	−35 18 32.6	9.083	0.924
	10 48 55	22	20 , 6	−3 43.17	− 3 3.8	22 7 38.94	−35 18 31.4	9.161	0.922
26	10 39 51	23	20 , 6	+1 3.67	+ 4 32.3	22 9 7.30	−35 10 41.7	9.111	0.923
	10 52 6	24	20 , 6	−5 50.76	− 9 39.8	22 9 8.69	−35 10 41.6	9.198	0.920
28	10 19 53	25	19 , 6	−1 7.11	+ 7 31.1	22 12 5.07	−34 53 55.5	8.968	0.925
	10 39 10	26	20 , 6	−4 12.99	+ 5 45.5	22 12 6.29	−34 53 48.9	9.144	0.924
30	10 15 33	27	20 , 6	+3 54.57	− 3 9.2	22 15 4.85	34 35 25.7	8.973	0.924
	10 30 13	28	20 , 6	+3 48.01	+ 7 23.3	22 15 5.18	−34 35 20.5	9.109	0.922
Oct. 4	9 46 30	29	20 , 6	+2 8.29	− 7 15.3	22 21 4.65	−33 54 12.2	8.677	0.925
	9 56 38	30	19 , 6	+0 59.00	− 1 24.0	22 21 4.79	33 54 7.5	8.855	0.924
5	10 0 0	29	20 , 6	+3 39.25	+ 3 32.7	22 22 35.59	−33 42 51.4	8.950	0.923
	10 12 55	30	20 , 6	+2 30.30	+ 9 56.8	22 22 36.07	−33 42 46.9	9.062	0.921
6	9 55 30	31	20 , 6	−5 14.81	− 5 19.4	22 24 6.84	−33 31 27.1	8.903	0.923
	10 23 54	32	20 , 6	+7 15.15	− 7 8.6	22 24 8.07	−33 31 9.0	9.164	0.917
Nov. 1	8 41 25	33	20 , 6	−3 32.78	− 0 5.8	23 4 2.53	−27 17 42.7	8.692	0.907
	8 55 11	34	20 , 6	−1 48.92	+ 8 20.0	23 4 3.54	−27 17 35.4	8.901	0.905
2	8 26 51	35	20 , 6	−2 19.38	− 5 3.0	23 5 34.85	−27 1 40.1	8.345	0.906
	8 37 56	36	10 , 0	−2 35.05	. . .	23 5 35.68	. . . .	8.669	. .
	8 44 59	36	0 , 6	. . .	+ 3 44.3	. . . .	−27 1 21.5	. .	0.905
6	8 23 25	37	20 , 6	−1 57.61	+ 5 31.3	23 11 47.84	−25 55 55.3	8.548	0.902
	8 43 49	38	17 , 6	+2 13.61	−10 7.8	23 11 49.01	−25 55 41.4	8.902	0.901

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 0 50.75	+4.94	−28 4 3.4	+19.5	Argentine General Catalogue 28937
2	21 6 9.29	+4.93	−28 0 26.6	+20.0	" " " 29061
3	21 3 17.93	+4.95	−28 30 57.0	+19.7	" " " 29001
4	21 6 18.05	+4.94	−28 19 2.0	+20.0	" " " 29068
5	21 3 39.78	+4.98	−29 13 45.3	+19.5	" " " 29008
6	21 4 28.44	+4.96	−28 54 3.8	+19.6	" " " 29030
7	21 10 1.95	+5.13	−32 14 3.4	+19.7	" " " 29164
8	21 18 36.27	+5.10	−31 54 43.7	+20.6	" " " 29328
9	21 28 23.26	+5.19	−34 15 14.0	+20.6	" " " 29524
10	21 16 42.16	+5.20	−34 5 54.7	+19.4	" " " 29293
11	21 26 8.15	+5.19	−34 23 21.9	+20.2	" " " 29490
12	21 20 46.06	+5.20	−34 20 49.4	+19.7	" " " 29376
13	21 26 29.30	+5.21	−34 47 18.4	+20.1	" " " 29492
14	21 29 7.07	+5.20	−34 46 30.9	+20.4	" " " 29539
15	21 35 11.90	+5.26	−36 2 37.1	+19.8	" " " 29664
16	21 36 38.02	+5.25	−36 2 29.8	+20.0	" " " 29698
17	21 38 33.57	+5.24	−36 4 34.2	+20.0	" " " 29733
18	21 41 38.01	+5.24	−36 5 29.4	+20.2	" " " 29791
19	21 42 8.03	+5.24	−36 18 28.2	+19.7	" " " 29806
20	24 47 34.10	+5.24	−36 18 28.2	+20.2	" " " 29928
21	22 5 30.86	+5.08	−35 26 12.2	+20.0	" " " 30321
22	22 11 17.33	+5.08	−35 15 47.8	+20.5	" " " 30421
23	22 7 58.57	+5.06	−35 15 31.2	+20.2	Argentine Zone Catal. XXII, 196
24	22 14 54.40	+5.05	−35 1 22.5	+20.7	Argentine General Catalogue 30497
25	22 16 7.14	+5.04	−35 1 47.1	+20.5	" " " 30514
26	22 16 14.24	+5.04	−34 59 55.0	+20.6	" " " 30516
27	22 11 5.27	+5.01	−34 32 36.4	+19.9	" " " 30416
28	22 11 12.12	+5.02	−34 43 3.7	+19.9	" " " 30418
29	22 18 51.43	+4.93 +4.91	−33 46 46.9	+20.0 +19.8	" " " 30575
30	22 20 0.86	+4.93 +4.91	−33 53 3.6	+20.1 +19.9	" " " 30596
31	22 29 16.76	+4.89	−33 26 28.3	+20.6	" " " 30783
32	22 16 47.74	+4.88	−33 24 20.1	+19.7	" " " 30533
33	23 7 30.81	+4.50	−27 17 57.8	+20.9	" " " 31493
34	23 5 47.93	+4.50	−27 26 16.2	+20.8	" " " 31468
35	23 7 49.75	+4.48	−26 56 57.9	+20.8	" " " 31503
36	23 8 6.24	+4.49	−27 5 26.6	+20.8	" " " 31507
37	23 13 40.97	+4.45	−26 1 47.6	+21.0	" " " 31599
38	23 9 30.96	+4.44	−25 45 54.5	+20.9	" " " 31529

RESULTS FOR LATITUDE AND ABERRATION OF OBSERVATIONS AT THE FLOWER OBSERVATORY. 1898–99.

By C. L. DOOLITTLE.

I have just derived the results of my latitude-work up to the end of September, 1899, and herewith inclose them. They are not quite homogeneous with those already published for the years 1896–98, since they depend on Struve's aberration-constant.

A preliminary reduction gives for this constant the value,

Aberration-constant, **20″.56**,

agreeing well with that given by the earlier series, namely, 20″.58.

	φ	No. Obs.
	° ′ ″	
1898 Sept. 6 – Sept. 16	39 58 2.372	57
Sept. 17 – Sept. 27	2.252	48
1898 Oct. 8 – Oct. 20	39 58 2.221	125
Oct. 22 – Nov. 3	2.167	139
Nov. 4 – Nov. 25	2.165	126
Dec. 16 – Jan. 11	2.033	104
1899 Jan. 14 – Feb. 5	2.001	102
Feb. 8 – Feb. 20	1.965	124
Feb. 21 – Mar. 12	1.928	126
Mar. 16 – Apr. 12	1.997	99
May 9 – May 25	2.070	155
May 26 – June 8	2.065	134
June 10 – July 1	2.136	97
July 2 – July 26	2.160	164
July 30 – Aug. 17	2.265	167
Sept. 13 – Sept. 28	2.211	90
		1851

Flower Observatory, Upper Darby, Penn., 1900 *Jan.* 4.

SUNSPOT OBSERVATIONS.

MADE AT BERWYN, PENN., WITH A $4\frac{1}{2}$-INCH REFRACTOR.

By A. W. QUIMBY.

1899		Time	New Grs.	Total Grs.	Total Spots	Fac. Grs.	Def.
July	1	5	1	2	22	1	fair
	2	8	–	2	14	1	fair
	3	3	1	2	22	1	fair
	4	4	1	3	29	2	v.good
	5	6	–	2	9	1	poor
	6	11	–	1	2	1	poor
	7	7	–	2	5	2	fair
	8	4	–	1	2	1	poor
	9	4	1	2	12	2	fair
	10	7	–	2	12	2	fair
	11	8	–	2	19	2	v.good
	12	7	–	2	10	–	fair
	13	7	–	1	2	–	poor
	14	8	1	2	7	1	fair
	15	7	–	2	5	1	poor
	16	8	–	1	1	1	v. poor
	17	8	–	–	–	–	poor
	18	8	–	–	–	–	fair
	19	8	–	–	–	1	fair
	20	8	–	–	–	1	fair
	21	8	–	–	–	1	fair
	22	8	–	–	–	1	fair
	23	1	–	–	–	1	poor
	24	8	–	–	–	1	fair
	25	11	–	–	–	–	poor
	26	10	1	1	8	1	fair
	27	7	–	1	4	1	poor
	28	7	–	1	2	1	poor
	29	8	–		–	1	fair
	30	4	–	2	4	2	fair
	31	8	–	–	–	3	good
Aug.	1	8	1	1	1	2	good
	2	8	–	1	1	1	fair
	3	8	–	–	–	1	fair
	4	7	–	–	–	–	fair
	5		–	–	–	1	fair
	6	8	–	–	–		fair
	7	8	–	–	–	–	poor
	8	8	–	–	–	1	fair
	9	8	–	–	–	–	fair
	10	3	–	–	–	–	fair
	11	11	–	–	–	–	poor
	12	4	–	–	–	–	fair
	13	8	–	–	–	1	fair
	14	8	–	–	–	–	poor
	*15	8	–	–	–	–	poor
	*16	8	–	–	–	–	poor
	17	8	–	–	–	–	fair
	*18	7	–	–	–	–	poor
	19	11	–	–	–	–	poor
	20	3	–	–	–	–	fair
	21	8	–	–	–	–	fair
	22	8	–	–	–	–	fair
	23	8	–	–	–	–	fair
	24	8	–	–	–	–	fair
	25	8	–	–	–	–	fair
	26	9	–	–	–	1	poor
	27	4	1	1	1	1	fair
	28	9	1	1	1	2	fair
Aug.	29	10	–	–	–	–	fair
	30	4				1	poor
	31	10	–	–	–	–	poor
Sept.	1	4	–	1	1	–	fair
	2	10			–		poor
	3	8	–			–	fair
	*4	7	–	–	–	–	fair
	*5	8	–	–	–	–	fair
	*6	7	–	–	–	–	fair
	*7	7	–	–	–	–	fair
	*8	7	–	–	–	–	fair
	*9	8	–	–	–	–	fair
	*10	7	–	–	–	–	fair
	*11	1	–	–	–	–	poor
	*12	7	–	–	–	–	poor
	*13	7	–	–	–	–	fair
	14	9	–	–	–	–	fair
	15	8	–	–	–	–	fair
	16	8	–	–	–	–	fair
	17	8	–	–	–	–	fair
	18	9	1	1	2	1	fair
	19	8	–	1	2	1	good
	20	5	1	2	4	3	good
	21	8		0	0	2	fair
	22	10		–	–	1	fair
	23	8		–	–	1	fair
	24	9			–	1	fair
	25	8				–	poor
	26	10	1	1	18		fair
	27	8	–	1	22	–	fair
	28	8	–	1	16	–	fair
	29	9	–	1	19	1	fair
	30	7	–	1	5	1	fair
Oct.	1	8		1	2	2	fair
	2	8	–	–	–	1	fair
	3	8	–	–	–	–	fair
	4	8	–	–	–	–	fair
	5	8	–			–	fair
	6	2	–			–	v. poor
	7	4	–	–	–	–	fair
	8	8			–	–	fair
	9	4	1	1	3	1	fair
	10	8	–	1	2	2	fair
	11	4	–	1	1	1	poor
	12	9		1	1		fair
	13	8		–	–	–	fair
	14	8	–	–			fair
	15	9			–	–	fair
	16	11		–			poor
	17	4	–	–			fair
	18	9	–				fair
	19	8	–				fair
	20	8	–	–	–	–	fair
	21	8	–	–	–	–	fair
	22	8	–	–	–	–	fair
	23	8	1	1	4	1	fair
	24	11		1	16	1	poor
	25	8	–	.	23	1	fair
	26	8	1	2	41	1	fair
Oct.	27	8	1	2	58	–	fair
	28	4	–	2	23	1	poor
Nov.	2	8	–	1	1	1	fair
	3	8	–	–	–	–	poor
	4	8	–	–	–	–	fair
	5	8	–	–	–	–	fair
	6	8	–	–	–	–	fair
	7	8	–	–	–	–	fair
	8	8	–	–	–	–	fair
	9	8	–	–	–	–	fair
	10	8	–	–	–	–	fair
	11	11		1	1	2	fair
	12	8	–	1	1	1	poor
	13	3	–	1	5	1	fair
	14	8	–	1	2	–	poor
	15	8	–	1	5		fair
	16	2	–	1	6	–	fair
	18	10	1	2	6	–	poor
	19	2	–	1	1	1	fair
	20	8	–	1	1	2	fair
	21	8	–	–	–	1	fair
	22	8	–	–	–	1	fair
	24	9	1	1	1	–	fair
	25	3	–	1	3	–	fair
	26	9	–	1	1		fair
	27	8	–	–	–		fair
	28	10	1	1	1	2	fair
	29	9	–	1	1	2	fair
	30	9	–	1	1	–	fair
Dec.	1	10	–	1	3	–	fair
	2	11	–	1	1	1	poor
	3	8	–	1	1		poor
	4	10	1	2	4	1	fair
	5	8	–	1	5	1	poor
	6	11	–	1	7	–	poor
	7	7	–	1	3	–	poor
	8	2	–	1	1	2	fair
	9	2		–	–	1	fair
	10	1			–	1	fair
	11	8	–	–	–		fair
	12	3	2	2	5	2	fair
	13	8	–	2	7	2	fair
	14	9	1	3	11	1	fair
	15	9		3	10	3	poor
	16	12		3	9	3	poor
	17	2		3	13	1	poor
	18	9	–	2	7	1	[illegible]
	19	8		1	1		poor
	20	9		1	1	1	fair
	21	8	–	–		1	fair
	22	8		–	–		fair
	24	4				1	fair
	25	10		–	–	2	fair
	26	9	–				fair
	27	9					fair
	28	3	–	1	3		fair
	29	10	–	1	6	–	fair
	30	9		1	1	–	poor
	31	9	–	1	1		good

* Made with $2\frac{1}{2}$-inch refractor.

LATITUDE-OBSERVATIONS MADE AT THE IMPERIAL ASTRONOMICAL OBSERVATORY AT KASAN,

By M. A. GRATCHOF, Observer of the Observatory.

[Communicated by Prof. D. Dubiago, Director.]

Series V. (1)

Date	φ 55° 47′+ ″	Pairs
1898 Sept. 12	23.13	15
13	23.18	8
20	22.85	3
25	23.18	15
30	23.31	3
Oct. 2	23.18	8
9	23.25	17
10	23.13	9
17	23.36	17
Nov. 5	23.23	8
9	23.32	17
11	23.44	10
22	23.46	16
23	23.51	7
Dec. 7	23.32	12
10	23.32	18
18	23.46	4
19	23.48	10
21	23.32	8
24	23.49	9
29	23.41	7
1899 Jan. 27	23.38	17
29	23.39	8
30	23.54	6
31	22.81	1
Feb. 5	23.45	20
6	23.32	11

Date	φ 55° 47′+ ″	Pairs
1899 Feb. 7	23.32	16
8	23.32	7
11	23.55	8
15	23.47	16
17	23.70	16
25	23.35	16
Mar. 3	23.25	10
4	23.40	16
6	23.24	16
8	23.39	7
25	23.68	10
27	23.49	3
29	23.48	15
Apr. 4	23.43	2
5	23.38	15
7	23.32	11
10	23.23	15
11	23.20	15
13	23.32	9
20	23.33	15
30	23.31	23
May 9	23.21	13
14	23.11	11
18	23.31	3
22	23.22	13
25	23.39	15
26	23.31	15
June 5	23.08	2
6	22.89	4

Date	φ 55° 47′+ ″	Pairs
1899 July 1	23.14	3
3	22.96	19
5	23.11	19
12	23.13	19
13	23.19	18
14	22.89	10
18	22.88	17
20	23.02	17
Aug. 5	23.14	4
11	22.78	15
18	22.92	2
19	22.92	15
20	23.01	10
22	22.75	6
23	22.93	15
24	23.04	15
Sept. 3	23.24	1
4	23.11	8
12	23.14	15
13	22.88	14
16	22.83	1
22	22.98	15
23	22.90	1
25	22.91	15
26	23.01	15
30	23.04	22
Oct. 2	22.98	17
3	23.03	17
4	23.02	17

Monthly Means.

Date		φ 55° 47′+ ″	Pairs
1898 Sept. 18	1898.72	23.149	44
Oct. 11	.77	23.255	51
Nov. 15	.87	23.390	58
Dec. 16	.96	23.384	68
1899 Jan. 28	1899.08	23.395	32
Feb. 12	.12	23.442	110
1899 Mar. 13	1899.20	23.402	77
Apr. 15	.29	23.300	108
May 21	.39	23.236	76
July 12	.53	23.040	122
Aug. 19	.63	22.927	82
Sept. 20	.72	23.006	107
Oct. 3	.76	23.010	51

(1) Continued from Series IV, *A.J.* 454.

CONTENTS.

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ON THE DISTRIBUTION OF THE MEAN MOTIONS OF THE MINOR PLANETS,

By SIMON NEWCOMB.

It was, I believe, first pointed out by KIRKWOOD, that if the mean motions of the minor planets are arranged in the order of magnitude, gaps will be found at the values which would have a simple relation of commensurability with the mean motion of *Jupiter*. This fact was yet more strongly brought out in a report to the *Astronomische Gesellschaft* in 1885 (*Vierteljahrsschrift*, XX, p. 234), where the distribution is shown graphically.

The first inference from this fact would be that the gaps in question are due to or connected with the large perturbations to which planets having mean motions of the missing values would be subject. But mature consideration would show difficulties in the way of accepting this explanation. It is doubtful whether there would be any instability how near so ever a mean motion would approach to commensurability; and, in any case, the limits between which the mean motions would have to be contained in order that extraordinary perturbations might arise are so narrow that, in a chance distribution, the corresponding gap might pass unnoticed. It therefore becomes of interest to investigate the fact as shown by the larger number of mean motions now at command. This I have done in the following way.

The mean motions of the minor planets (1) to (400), as found in the *Berliner Jahrbuch* for 1900, were classified according to their amount. Those less than 500″, or greater than 1000″, were left out of the count. Between these limits they were grouped by intervals of 10″. The count was made separately for the first 200, and the second 200. The result is shown in the following table. Column μ gives values of the mean motion. The next three columns give the number of planets whose mean motion lie between μ and $\mu + 10''$: column (1) for (1) to (200); (2), for (201) to (400); and (3), from (1) to (400).

The comparison of columns (1) and (2) shows, as we should expect, a slight relative excess in the smaller motions for the second 200 discovered. Otherwise the comparison need not interest us except as an example of chance deviations. What we are mainly concerned with is column (3). A little study of this shows that what we have to do with is not merely gaps in the series, but also a tendency toward accumulation near certain values of μ; in short, a regular progression in the frequency.

μ ″	(1)	(2)	(3)	μ ″	(1)	(2)	(3)
500	0	0	0	750	1	8	9
10	0	0	0	60	9	13	22
20	0	0	0	70	13	12	25
30	0	0	0	80	10	8	18
40	2	0	2	90	8	3	11
50	2	1	3	800	5	5	10
60	1	3	4	10	11	5	16
70	1	0	1	20	5	4	9
80	0	0	0	30	6	4	10
90	0	0	0	40	3	4	7
600	0	0	0	50	10	1	11
10	3	3	6	60	3	2	5
20	6	3	9	70	1	2	3
30	9	10	19	80	1	1	2
40	11	16	27	90	0	0	0
50	3	5	8	900	1	0	1
60	3	7	10	10	3	3	6
70	2	3	5	20	6	0	6
80	5	7	12	30	8	1	9
90	1	2	3	40	5	3	8
700	0	2	2	50	4	2	6
10	3	5	8	60	6	5	11
20	3	8	11	70	8	1	9
30	6	4	10	80	1	4	5
40	0	1	1	90	1	3	4
Sum.	61	80	141	Sum.	129	94	223

The first question which arises is whether the inequalities in column (3) can be the result of accident. This question may be answered by considering that, between 600″ and 1000″ there are 354 μ's, divided into 40 groups. Assuming that each μ was as likely to fall into one group as another, we may readily compute the respective probabilities that a group taken at random would contain 0, 1, 2, . . . n, . . . μ's. The following are the values of the probability p for different values of n.

n	p	n	p	n	p	n	p
0	.000	5	.064	10	.118	15	.017
1	.001	6	.095	11	.095	16	.009
2	.005	7	.121	12	.070	17	.005
3	.016	8	.135	13	.047	18	.002
4	.035	9	.134	14	.029	19	.001

Multiplying the values of p by 40 we shall have the probable number of groups containing 0, 1, 2, ... n, ... μ's. We thus see that the probability is very small that any one group would contain less than 2 or more than 17 μ's. That there should be 3 groups each containing more than 20, and 3 others containing 0 or 1 is out of the question. Still less could it happen that these extreme cases should be grouped together as they are.

Returning to column (3) we see that the values of μ are most deficient near 600″, 700″, 745″, and 900″. The μ of *Jupiter* being 299″, the deficiencies correspond to the ratios

2 : 1; 7 : 3; 5 : 2; 3 : 1

with respect to *Jupiter*. The coincidence is too close to be the result of accident, so that there is undoubtedly some cause which tends to prevent minor planets having mean motions of these values.

On the other hand there is an equally well-marked tendency to cluster around two of the intermediate values, namely near 640″ and 775″, which cannot be attributed to chance.

It will be seen by the first table that there are no μ's between 500″ and 540″. This fact leads us to examine the values less than those grouped in the table. There are five such, all contained between the limits 400″ and 460″. It is noteworthy that two of them have a ratio of very nearly 3 : 2 to the μ of *Jupiter*. We have

$$\tfrac{3}{2} J = 448''.9$$
$$(153) = 449.8$$
$$(361) = 449.9$$

The two latter are osculating values which may deviate from the mean values by one or more seconds. We conclude that the ratio 3 : 2 to the mean motion of *Jupiter* is not one which the minor planets tend to avoid.

The gap from 460″ to 540″ is so wide that we might almost regard those outside of it as a separate group. But it will not be safe to do so till we see whether it may not be filled by subsequent discoveries.

I do not see that these inequalities of distribution could have arisen in a group of such bodies once uniformly distributed. We must therefore consider its origin as cosmogonical, and belonging to a period when the matter of these bodies formed a continuum. Its explanation on this hypothesis I leave to others.

SMALL STARS NEAR *SIRIUS*.

By E. E. BARNARD.

In *A.J.* 420, Vol. XVIII, p. 93, I have given some measures of small stars near *Sirius*. The stars *E* and *F* do not belong to *Sirius*, and are being left behind. *Sirius* will ultimately approach very close to the star *E*, passing some 8″ preceding it in a little over forty years hence.

I have measured these two stars again. These are here included with the previous measures in 1897.

AE $E = 16^{M}$

	°	″
1897.841	195.4	57.69
98.739	194.0	56.80
99.883	193.7	54.70

AF $F = 16\tfrac{1}{2}^{M}$

	°	″
1897.841	3.0	50.08
99.845	4.6	53.12
99.864	. .	53.10

These stars strongly show the motion of *Sirius*. I have also measured two other small stars nearer to *Sirius*. They are *H* and *K*.

AH

	°	″
1899.845	281.1	40.25
99.883	280.0	. .

AK

	°	″
1899.864	22.4	29.53

This star was also referred to *F*, which star it follows, south.

FK

	°	″
1899.864	163.6	26.05
99.883	164.6	26.35

K is about 16^{M}. It lies almost exactly in the line of motion of *Sirius*, and ought to show in six months' time if it is going with the large star.

The star *H* is about 16^{M}. It has not appeared stellar at any time, and I am under the impression it must be a very small nebula. These objects are shown to be real by a reversal of the telescope and change of eyepieces.

The motion of *Sirius* seems to be 1″.313 annually in the direction 204°.0.

There are quite a number of small stars near *Sirius*, some of which I shall measure later. One of these, *G*, is

AG

	°	″
1899.169	249.0	86.78

Yerkes Observatory, Williams Bay, Wis., 1899 *Nov.* 23.

NOTE ON THE COMPANION OF *SIRIUS*,

By E. E. BARNARD.

The early mornings of October 29 and 30 were exceptionally steady, and the companion of *Sirius* was observed with the 40-inch.

Following are the measures, which were quite satisfactory:

	°	″
1899.829	151.16	4.91
.831	151.17	4.76
1899.830	151.31	4.83

Mr. H. J. Zwiers has given an orbit and ephemeris of the companion in the Proceedings of the *Koninklijke Akademie Wetenschappen Te Amsterdam*, for 1899 June 20. The title of the paper is, "The System of *Sirius* According to the Latest Observations." The period derived by Mr. Zwiers is, I believe, the smallest yet obtained, viz.: 48.8421 years.

The position of the companion for the date above is

150°.20 4″.46

A comparison gives

O−C +1°.11 +0″.37

I do not think the distance in the observations can be out as much as this. If the observations represent the true place of the companion the ephemeris-distances are too small, and perhaps the angles also.

Yerkes Observatory, Williams Bay, Wis., 1899 Nov. 2.

OBSERVATIONS OF TEMPEL'S SECOND COMET = *c* 1899 IV,

MADE AT THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA,

By C. D. PERRINE.

1899	Mt. Hamilton M.T.	✱	No. Comp.	☄ − ✱ Δα	Δδ	☄'s apparent α	δ	log pΔ for α	for δ	Telescope
	h m s			m s	′ ″	h m s	° ′ ″			
May 11	14 9 13	1	10 , 8	+1 42.45	−2 49.6	19 1 23.13	−4 13 43.4	n9.258	0.764	36
12	13 46 32	2	4	. . .	+2 20.0	. . . .	4 10 29.6	. .	0.762	36
	13 57 27	2	4	−1 54.62	. . .	19 3 2.05	. . . .	n9.307	. .	36
	14 16 13	3	d10 , 8	+0 8.09	+1 40.9	19 3 3.09	4 10 25.6	n9.223	0.763	36
14	14 24 40	4	d10 , 8	−0 3.47	−1 39.5	19 6 21.40	4 4 19.5	n9.152	0.763	36
19	13 27 35	5	d10 , 8	−0 0.21	+0 31.1	19 14 25.07	3 52 39.0	n9.364	0.760	36
20	14 17 55	7	d10 , 8	−0 1.15	−1 5.1	19 16 4.81	3 50 55.2	n9.107	0.762	36
June 3	12 49 47	9	d 8 , 6	−0 0.69	+4 17.4	19 37 43.77	3 59 40.3	n9.364	0.760	36
4	12 39 33	11	10 , 6	+1 56.48	+2 31.9	. . . .	. . . .	n9.387	0.760	36
9	15 4 59	12	10 , 6	+1 1.39	+2 41.2	. . . .	. . . .	n8.833	0.768	36
10	13 49 4	13	10 , 6	+2 23.67	−3 33.1	. . . .	. . . .	n8.924	0.768	36
14	14 47 58	14	10 , 6	−3 3.32	−1 35.0	19 53 50.33	5 7 42.9	8.708	0.775	12
15	13 32 2	15	10 , 8	−1 42.89	−0 40.2	19 55 10.20	5 16 42.6	n8.964	0.775	36
16	13 10 53	16	10 , 6	+3 55.54	+0 14.2	19 56 34.59	5 27 2.0	n8.845	0.777	36
19	14 42 26	17	12 , 8	+0 46.08	+2 28.3	20 0 47.30	6 2 15.3	8.857	0.782	12
21	13 1 9	18	10 , 8	−1 44.87	−0 35.0	20 3 25.69	6 28 3.1	n9.093	0.783	36
30	11 59 55	19	10 , 8	−4 1.52	+1 58.1	20 15 19.25	9 3 33.7	n9.299	0.799	36
July 1	14 57 54	20	12 , 8	+1 34.53	+3 9.0	20 16 45.42	9 27 26.5	9.223	0.802	36
4	13 21 50	21	10 , 8	+0 55.29	+2 50.6	20 20 29.78	10 34 14.5	n8.114	0.814	12
5	12 28 47	22	d10 , 8	+0 30.50	−1 52.6	20 21 42.81	10 57 38.9	n9.076	0.816	12
5	12 50 11	23	d10 , 8	+0 7.75	+4 41.8	20 21 43.55	10 57 56.9	n8.863	0.817	12
6	12 56 53	24	d10 , 8	−0 9.64	+1 58.0	20 22 59.39	11 23 14.0	n8.740	0.820	36
7	13 9 11	25	10 , 8	+2 35.01	+3 22.4	20 24 14.48	11 49 4.5	n8.342	0.823	36
9	12 46 6	26	10 , 8	−1 49.66	−1 41.7	20 26 42.07	12 42 13.8	n8.763	0.829	36
11	13 12 3	27	10 , 8	+0 29.81	+4 58.3	20 29 10.38	13 38 53.5	7.903	0.836	12
12	12 51 23	28	10 , 8	+1 44.06	−3 44.2	20 30 22.58	14 7 35.4	n8.431	0.838	12
13	13 9 7	29	10 , 8	−1 12.37	−0 41.5	. . . .	. . . .	8.041	0.841	36
14	10 49 9	30	10 , 8	−0 36.45	−1 43.2	20 32 13.12	15 4 36.5	n9.436	0.825	36
15	14 10 26	31	10 , 8	+0 41.18	−1 23.4	. . . .	. . . .	9.188	0.837	36
29	12 46 20	32	10 , 8	+1 27.72	−1 15.8	20 50 44.19	23 15 3.3	8.778	0.884	36
Sept. 23	9 56 48	33	d10 , 8	+0 5.01	−2 16.3	. . . .	. . . .	7.903	0.926	36
24	9 54 54	34	10 , 8	+0 34.87	+0 0.5	22 6 10.84	35 25 51.6	8.000	0.927	36
Oct. 2	10 36 47	35	d10 , 8	−0 13.58	−1 5.0	22 18 10.32	34 14 46.1	9.201	0.915	36
Nov. 22	8 16 18	36	d10 , 8	+0 0.65	−0 58.9	23 36 49.73	21 25 50.7	9.009	0.874	36
Dec. 1	7 29 32	38	d10 , 8	+0 9.93	+3 37.3	23 50 51.49	−18 51 3.2	8.672	0.866	36

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	18 59 37.69	+2.99	− 4 10 53.2	− 0.6	½ (Rad.$_3$ 5041 + Cord. Gen. Catal. 26133)
2	19 4 53.67	+3.00	4 12 49.5	− 0.1	W. Bessel 27
3	19 2 52.00	+3.00	4 12 6.3	− 0.2	Micrometer-comparison with *2
4	19 6 21.82	+3.05	4 2 40.2	+ 0.2	W. Bessel 65
5	19 14 22.15	+3.13	3 53 11.3	+ 1.2	Micrometer-comparison with *6
6	19 17 15.03	+3.12	3 54 34.5	+ 1.1	Rad.$_3$ 5142
7	19 16 2.82	+3.14	3 49 51.6	+ 1.5	Micrometer-comparison with *8
8	19 17 6.94	+3.14	3 49 32.0	+ 1.5	½ (M$_1$ 19844 + W.B. 352)
9	19 37 41.04	+3.42	4 4 2.8	+ 5.1	Micrometer-comparison with *10
10	19 36 4.33	+3.43	4 5 6.1	+ 5.0	W. Bessel 862
11	19 37 13.00	+3.45	4 5.9	+ 5.2	S.DM. −4°4890
12	19 45 34.6	+3.56	4 31.6	+ 6.8	S.DM. −4°4949
13	19 45 34.6	+3.59	4 31.6	+ 7.0	S.DM. −4°4949
14	19 56 50.01	+3.64	5 6 16.2	+ 8.3	W. Bessel 1374
15	19 56 49.43	+3.66	5 16 10.9	+ 8.5	½ (Rad.$_3$ 5362 + Cord. Gen. Catal. 27449)
16	19 52 35.35	+3.70	5 27 21.6	+ 8.4	M$_2$ 9532
17	19 59 57.47	+3.75	6 4 53.1	+ 9.5	Schjellerup 7789
18	20 5 6.77	+3.79	6 27 38.4	+10.3	Rad.$_3$ 5408
19	20 19 16.78	+3.99	9 5 44.4	+12.6	Rad.$_3$ 5484
20	20 15 6.87	+4.02	9 30 48.3	+12.8	W. Bessel 300
21	20 19 30.40	+4.09	10 37 18.8	+13.7	M$_1$ 24309
22	20 21 8.19	+4.12	10 56 0.3	+14.0	Schjellerup 8036
23	20 21 31.68	+4.12	11 2 52.8	+14.1	M$_1$ 24470
24	20 23 4.88	+4.15	11 25 26.3	+14.3	W. Bessel 510
25	20 21 35.29	+4.18	11 52 41.3	+14.4	Schjellerup 8042–3
26	20 28 27.51	+4.22	12 41 17.3	+15.2	½ (Cord. Gen. Catal. 28180 + Rad.$_3$ 5530)
27	20 28 36.30	+4.27	13 44 7.2	+15.4	W. Bessel 648
28	20 28 34.23	+4.29	14 4 6.7	+15.5	½ (Cord. Gen. Catal. 28183 + Rad.$_3$ 5531)
29	20 32 45.2	+4.30	14 37.9	+16.0	S.DM. −14°5805
30	20 33 15.25	+4.32	15 3 9.4	+16.1	M$_1$ 25356
31	20 33 14.9	+4.35	15 38.4	+16.2	S.DM. 15°5738
32	20 49 11.76	+4.71	23 14 6.1	+18.6	A.O. 16477
33	22 4 30.7	+5.09	35 30.4	+20.1	Cord. DM. −35°15185
34	22 5 30.89	+5.08	35 26 12.2	+20.1	Cord. Gen. Catal. 30321
35	22 18 18.93	+4.97	34 14 1.3	+20.2	Cord. Gen. Catal 30563
36	23 36 44.80	+4.28	21 25 13.1	+21.3	Micrometer-comparison with *37
37	23 33 25.60	+4.27	21 25 36.7	+21.2	Cord. Gen. Catal. 31972
38	23 50 37.38	+4.18	18 58 1.7	+21.2	Micrometer-comparison with *39
39	23 48 33.63	+4.17	−18 55 36.6	+21.2	Cord. Gen. Catal. 32245

NOTES.

In observations marked *d*, $\Delta\alpha$ was measured directly with the micrometer.

May 7th, Comet is very small, and hard to distinguish from a star. Less nebulous than last night. Some haze. — 11th, Comet 14½^M–15^M, and has a decided central condensation. — 12th, Comet brighter than last night, 13^M; 15″ diameter; bright central condensation. Wind shaking telescope. — 19th, Comet very small, not over 5″ diameter. Almost stellar, very little nebulosity. 14^M, or fainter. Seeing and sky good.—20th, Comet very small and condensed: 5″ or 6″ diameter; 14½^M, brighter at the center.—*June* 3d, Comet brighter, 13^M; 15″ diameter. Comet has a sharp condensation, and is almost stellar in appearance. Sky not very pure. — 4th, Comet fully 12^M, and has a very sharp nucleus. — 9th, Comet much brighter, 11^M; 20″–30″ diameter; sharp central condensation. — 10th, Comet is 11^M, and has a sharp stellar nucleus of 12^M. Comet fully ½′ in diameter. — 14th, Comet 10½^M; sharp central condensation. Comet is about 1′ in diameter and is just visible in the 3½-inch finder of the 12-inch equatorial. — 15th, Examined comet with power of 520; nucleus resembles a star of 12^M. Comet has a fan-shaped extension for ½′ n. p. Seeing 4. — 16th, Comet 2′ in diameter. Nucleus stellar, 12^M. —19th, Comet 10^M, with a sharp stellar point of 11½^M or 12^M. Comet 1½′ or 2′ diameter. Coma slightly brighter on n. f. side.—21st, Comet 10^M. Seeing poor. — 30th, Comet 2′ diameter; 9^M; nucleus 10^M. Examined nucleus with powers of 270 and 520, and compared it with a star only 15″ distant. Nucleus is fully as sharp as the star, and does not differ from it in appearance, except in color; the star is yellow, while the nucleus of the comet is bluish green. Seeing 4. — *July* 1, Short fan-shaped tail n. p. — 4th, Comet about 9½^M; sharp stellar nucleus of 10½^M. There is a short fan-shaped tail n. p. for 1′, and a faint nebulosity surrounding all. Seeing 4. — 5th, Comet easy, 9½^M. Stellar nucleus of 11^M. Seeing 4. 6th, Wind sways telescope. Fan-shaped tail ½′ long n.p. Nucleus 10½^M, and just as sharp as a star with a power of 520. — 7th, Nucleus 11^M, and with a power of 520 does not differ from a star of same brightness in field 1′ distant. Diameter of the nucleus is certainly not greater than ¼″. Entire comet 5′ in diameter. Outer nebulosity very faint. — 9th, Comet 9^M; fan-shaped tail, 1′ long n. p., surrounded by nebulosity filling the 270-power field. Nucleus 10½^M or 11^M. — 11th, Comet 9^M: nucleus 11^M; stellar. — 12th, Comet about 9^M; stellar nucleus of 10½^M. Short fan-shaped tail n. p. — 13th, Comet 9^M: nucleus perfectly stellar, and 10^M.5. Short fan-shaped appendage n. p. nucleus. — 14th, Nucleus fully 10½^M. — 29th, Nucleus 10^M, and stellar. With a power of 520 the nucleus is still sharp, and differs in no way from the star images. Fan-shaped extension 1′ in length n. p. nucleus. — *Sept.* 23d. Comet 12^M; ½′ diameter; faint nucleus. Sky smoky. — 24th, Comet brighter than last night, 10^M; diameter 1′–2′; nucleus 13^M. Sky smoky. — *Oct.* 2d. Nucleus still visible. — *Nov.* 22d, Comet 14^M; ½′ in diameter. Seeing 2. — *Dec.* 1, Comet very faint; 15^M. Very diffuse. Diameter 1′. Almost no condensation.

Lick Observatory, University of California, 1900 *Jan.* 16.

OBSERVATIONS OF COMET 1898 X,

MADE WITH THE 12-INCH TELESCOPE OF THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA,

By WILLIAM J. HUSSEY.

1898 Mt. Hamilton M.T.		✳	No. Comp.	☄ − ✳ $\Delta\alpha$	☄ − ✳ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Oct. 27	8 4 44	1	8 , 8	−0 12.55	+2 49.0	16 37 35.23	+41 0 21.6	9.791	0.588
31	7 12 47	3	8 , 8	−0 12.55	+7 14.5	17 10 2.88	+29 48 35.5	9.707	0.541
Nov. 1	7 28 32	4	8	. . .	−6 16.9	. . . . .	+27 12 1.7	. .	0.587
5	6 59 28	5	8 , 8	+0 13.95	+2 29.7	17 35 9.23	+18 6 18.6	9.654	0.621
6	7 24 39	6	8 , 8	+1 28.96	+4 30.3	17 38 55.02	+16 4 30.9	9.667	0.656
	7 24 39	7	8 , 8	−0 54.36	+1 25.5	17 38 55.15	+16 4 32.4	9.667	0.656
7	7 54 49	8	8 , 8	+0 10.58	+6 10.1	17 42 21.51	+14 9 6.3	9.677	0.687
10	6 32 39	9	6 , 8	+0 3.09	−2 32.9	17 50 39.94	+ 9 10 57.4	9.616	0.672
11	7 5 10	11	8 , 8	−0 25.90	+7 16.3	17 53 5.41	+ 7 38 6.5	9.644	0.693
12	6 38 19	12	8 , 8	−0 42.82	−2 42.4	17 55 13.91	+ 6 13 42.0	9.622	0.693
13	6 50 3	13	8 , 8	+0 14.49	−1 12.1	17 57 15.05	+ 4 51 24.4	9.633	0.703
14	6 41 53	15	8 , 8	+0 12.14	+0 41.1	17 59 4.78	+ 3 34 18.1	9.626	0.709
	6 54 50	16	8 , 8	−0 13.73	−2 55.6	17 59 5.95	+ 3 33 41.3	9.638	0.711
	7 3 42	17	8 , 8	−0 12.81	+4 8.9	17 59 6.67	+ 3 33 12.1	9.644	0.712

Mean Places for 1898.0 of Comparison-Stars.

✳	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 37 46.92	+0.86	+40 57 30.8	+1.8	12 ± M. Connected with ✳2
2	16 40 38.01	+0.86	+40 56 58.4	+2.1	Deichmüller, Bonn A.G. Catal. 10697
3	17 10 13.96	+1.47	+29 41 16.6	+4.4	Graham, Cambridge, E., A.G. Catal. 8084
4	17 17 35.70	+1.59	+27 18 13.8	+4.8	" " " " 8158
5	17 34 53.21	+2.07	+18 3 44.1	+4.8	Auwers, Berlin A.G. Catal. 6375
6	17 37 24.01	+2.05	+15 59 56.0	+4.6	" " " " 6396
7	17 39 47.46	+2.05	+16 3 2.0	+4.9	" " " " 6415
8	17 42 9.00	+2.13	+14 2 51.6	+4.6	Weisse's Bessel 17^{h}802
9	17 50 34.59	+2.26	+ 9 13 25.9	+4.4	12 ± M. Connected with ✳10
10	17 50 28.94	+2.26	+ 9 16 38.6	+4.4	Bruns and Peter, Leipzig, A.G. Catal. 8166
11	17 53 29.00	+2.31	+ 7 30 45.9	+4.3	" " " " " 8200
12	17 55 54.38	+2.35	+ 6 16 20.1	+4.0	" " " " " 8225
13	17 56 58.20	+2.36	+ 4 52 32.5	+4.0	10 ± M. Connected with ✳14
14	17 54 2.62	+2.38	+ 4 57 49.0	+3.7	Boss, Albany A.G. Catal. 6013
15	17 58 50.21	+2.43	+ 3 33 33.1	+3.9	" " " " 6059
16	17 59 17.25	+2.43	+ 3 36 33.0	+3.9	" " " " 6064
17	17 59 17.05	+2.43	+ 3 28 59.3	+3.9	" " " " 6063

I am indebted to Mr. CODDINGTON for assistance in checking the reduction of these observations.

Mt. Hamilton, California, 1900 *Jan.* 20.

OBSERVATIONS OF THE PLANET (334) *CHICAGO*,

MADE WITH THE 12-INCH REFRACTOR OF THE LICK OBSERVATORY,

By WILLIAM J. HUSSEY.

1899 Mt. Hamilton M.T.		✳	No. Comp.	Planet − ✳ $\Delta\alpha$	Planet − ✳ $\Delta\delta$	Planet's Apparent α	Planet's Apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Aug. 3	10 29 32	1	8 , 8	+0 22.78	−0 18.9	20 15 48.26	−18 40 53.1	n9.075	0.858
4	9 30 39	2	8 , 8	−0 6.73	−5 28.4	20 15 14.41	−18 43 45.4	n9.358	0.846
24	10 49 8	3	8 , 8	−0 26.30	+3 35.7	20 4 12.57	−19 36 48.0	9.096	0.862
25	10 20 6	4	8 , 8	+0 16.35	+3 19.6	20 3 47.67	−19 38 56.3	8.859	0.865
31	10 9 39	5	8 , 8	+0 1.13	+0 26.6	20 4 34.43	−19 51 3.0	9.021	0.864
Sept. 1	9 48 41	5	8 , 8	−0 17.44	−1 23.7	20 4 15.89	−19 52 53.3	8.831	0.866

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 15 20.77	+1.71	−18 40 19.8	+15.6	13±M. Connected with *2
2	20 15 13.45	+1.71	−18 38 32.6	+15.6	Gould, Gen. Catal. 27876
3	20 4 34.17	+1.70	−19 40 38.0	+14.3	Stone, Radcliffe Catal. 5407
4	20 3 26.63	+1.69	−19 42 30.1	+14.2	Yarnall 8912
5	20 1 28.63	+1.67	−19 51 43.5	+13.9	Weiss's Argelander 15918

Mt. Hamilton, Cal., 1900 *Jan.* 18.

NOTES ON CERTAIN SOUTHERN SHORT-PERIOD VARIABLES,

BY ALEXANDER W. ROBERTS.

The following notes deal only with variables recently discovered.

C.P.D. −41°1681.

R.A. $7^h\ 42^m\ 41^s$, Decl. −41° 4′.0 (1875).

An examination of this star made at Lovedale during October and November supports INNES's discovery that the star is an *Algol*-variable. The period may be either 6.45 days, or 12.90 days with a secondary minimum midway between two chief minima. The star is stationary at the minimum phase for some hours.

The elements of variation resulting from a comparison of my own with INNES's earlier observations are:

Epoch: Max. 1900 January 8.0 G.M.T.
Period: 12.70 days
Min. to Max. 4.0 days

The amplitudes of variation resulting from my observations, 9M.0–10M.4. are slightly greater than those obtained by Mr. INNES.

Arg. Z.C. 3227.

R.A. $7^h\ 44^m\ 2^s$, Decl. −42° 11′.8 (1875).

This star, which has been constantly used as a comparison-star for *W Puppis*, varies between the limits 7M.8 and 8M.5.

A period has not yet been determined, but there is every indication that it is short.

Arg. G.C. 10946. Z.C. 679.

R.A. $8^h\ 8^m\ 16^s$, Decl. −34° 12′.2 (1875).

This star was marked variable on a chart, sent me by Mr. INNES, with the note, "period 0.41 days."

I am able to confirm the variation between the limits 7M.5 and 8M.5, but my observations are not full enough to yield a good period.

C.P.D. −54°6634.

R.A. $15^h\ 32^m\ 42^s$, Decl. −54° 54′.4 (1875).

Observations made at Lovedale during September, October and November, confirm the variation of this star.

C.P.D. −49°10361.

R.A. $17^h\ 49^m\ 32^s$, Decl. −49° 24′.9 (1875).

The announcement of this star's variation was sent to me early in November by Mr. INNES; and observations were begun at once. Unfortunately the star was then too low down to allow of an extended series of observations on any one evening.

The elements resulting from my observations are:

Epoch: Max. 1900 January $1^d\ 6^h\ 30^m$ G.M.T.
Period: $7^h\ 28^m.0$
Min. to Max. $1^h\ 20^m$
Limits: 9M.0–10M.6

The variation of this star is exceedingly remarkable. Its ascending phase is, I think, the most rapid known; further, at minimum the light of the star is almost stationary for nearly four hours.

Lovedale, 1899 *December* 1.

THE DOUBLE STAR β 883,

BY E. E. BARNARD.

The following observations were made with the 40-inch:

	°	″
1898.665	47.2	. .
.668	44.6	0.20
.900	44.1	0.18
1898.744	45.3	0.19

The epoch for the distances would be 1898.784.

The observations were very difficult, and the distances are uncertain. They are doubtless too small. The last distance was a mere guess.

	°	″
1899.620	54.5	0.24
.829	56.1	0.21
.831	50.4	0.23
.845	54.9	0.22
1899.781	54.0	0.22

These last observations were made under better conditions.

Yerkes Observatory, Williams Bay, Wis., 1899 *Nov.* 10.

ON TWO VARIABLE STARS OF SHORT PERIOD, (*U VULPECULAE* AND *SU CYGNI*).

By PAUL S. YENDELL.

The announcement of the variability of these two stars, with observations, elements, and mean light-curves, were published by Müller and Kempf in *A.N.* 3483, and *A.J.* 431–2. A confirmation of variability, with slight corrections to the elements of variation, was published by Luizet in *A.N.* 3570, and the results of photometric observations at Harvard College Observatory in Circular No. 41.

I began observations on both stars, 1899 June 30, and followed them up until the middle of November, when I was compelled, very reluctantly to give up observing for the time, and have not yet resumed it. It is much regretted that a longer line of observations was not secured.

The stars are rather difficult of observation, and subject to complications introduced by their hour-angles, especially *U Vulpeculae*, and the agreement with the observations of the discoverers in respect to the limits of magnitude is not very close. The light-range found in each case, however, substantially agrees with theirs.

U Vulpeculae.

My observations of this star are fifty-six in number. By the use of the mean light-curve given by Müller and Kempf, and, in some instances, of the single curves, I have deduced from them the dates of ten maxima and eleven minima, which are given in the subjoined table. The dates marked with a star were found from the single curves.

Maxima	wt.	Minima	wt.
1899 July 3.79	4	1899 July 30.6	4
18.38	1	Aug. 9.17	2
Aug. 4.10	3	16.49	1
28.65	1	25.05	2
Sept. 4.45	1	Sept. 9.2*	3
13.0*	4	17.3*	3
20.6*	4	24.7*	2
Oct. 7.73	1	Oct. 3.00	3
14.32	1	10.32	1
Nov. 7.9*	2	Nov. 4.8*	2
		13.09	2

These dates, when compared with Müller and Kempf's elements, give a series of uniformly negative residuals, the mean for the maxima being $-1^d.32$, corresponding with the epoch 88, and for the minima $-0^d.9$, corresponding with the epoch 90.

The period indicated by the maxima is $7^d.985$. This agrees substantially with the value found by Pickering, H.C.O. Circular, No. 41, and contradicts Luizet's value of $8^d.003$.

SU Cygni.

My observations of the star number fifty-seven, and have all been reduced by Müller and Kempf's mean curve; on account of the star's short period, many of the dates are derived from single observations. I have seventeen maxima and eleven minima, as follows:

Maxima	wt.	Minima	wt.
1899 July 1.08	1	1899 June 30.30	1
4.78	1	July 31.62	1
17.42	1	Aug. 7.95	2
31.88	2	15.43	2
Aug. 4.56	1	31.88	2
8.46	1	Sept. 7.29	2
16.40	2	15.36	3
Sept. 1.67	2	21.89	2
8.65	1	30.32	1
12.37	1	Nov. 1.33	1
19.96	1	8.57	2
23.91	2		
27.47	2		
Oct. 1.39	1		
9.68	1		
Nov. 5.12	1		
12.72	2		

The minima being rather indefinitely marked, comparison with the elements of Luizet was made of the maxima only, showing a mean residual of $\pm 0^d.14$, with a probable error of $\pm 0^d.16$, for a single determination of weight 2, thus substantially confirming Luizet's results for this star

Dorchester, 1900 *Jan.* 21.

OBSERVATIONS OF MINOR PLANET (7) *IRIS*,

MADE WITH THE 5-INCH VERTICAL CIRCLE AT THE U. S. NAVAL OBSERVATORY,

By Assistant Astronomer GEORGE A. HILL.

1899 Washington M.T.		Apparent δ	log Δρ	C − O
	h m s	° ′ ″		″
Sept. 11	14 7 39	+20 6 26.1	0.448	+ 7.9
14	13 55 29	+20 11 35.6	0.446	+ 9.2
27	12 59 31	+20 3 35.4	0.449	+ 6.1
28	12 55 57	+20 0 49.1	0.450	+11.6
30	12 45 56	+19 54 21.3	0.453	+11.4
Oct. 1	12 41 21	+19 50 41.0	0.454	+12.4
3	12 32 9	+19 42 23.7	0.457	+11.4
13	11 45 15	+18 44 16.1	0.478	+12.0
19	11 17 1	+17 58 29.1	0.493	+11.9
21	11 7 13	+17 41 54.8	0.499	+10.2
24	10 53 47	+17 16 16.0	0.507	+ 8.3

The values C − O have been derived from a comparison with the Ephemeris as published in the *B.J.* for 1901. These declinations depend upon the adoption of latitude 38° 55′ 16″.66 for the Vertical Circle, and are measurements of double zenith-distances of the planet, by reversal of the instrument.

ON THE VARIABLE 2852 *V PUPPIS*.

By ALEXANDER W. ROBERTS.

Observations of this star made at Lovedale indicate that it is a variable of the *Algol*-type, with a period of about one and a half days.

It was suspected of variation in 1886 by STANLEY WILLIAMS, who suggested a period of 4.2 days (*Mon. Not., R. A. S.*, Vol. 47, p. 91). Observations made here in 1891 and 1892 indicated a much shorter period than this.

In 1896 Professor PICKERING announced that an examination of the Draper Memorial Photographs, taken at the Arequipa station, showed that the star is a spectroscopic binary, with a period of 3.115 days. As stated, my observations yield a period less than half this.

The elements obtained from the 1899 observations alone are as follows:

Full period,	$1^d\ 10^h\ 54^m\ 26^s.7$	
Epoch of first min.,	1900 January 1	$5^h\ 5^m$ (G.M.T.)
of second min.,	1	$23^h\ 0^m$
Mag. at first min.,	4.85	
at second min.,	4.65	
at maximum,	4.10	

The light-curve would indicate two stars, one slightly brighter than the other, revolving round one another in an almost circular orbit. The inclination of the orbit must be very small, and the distance between the two stars less than their semi-diameter.

OBSERVATIONS OF MINOR PLANET (7) *IRIS*,

MADE WITH 5.3-INCH MERIDIAN TRANSIT AT U.S. NAVAL OBSERVATORY,

BY M. E. PORTER.

No.	Date 1899	Wash. M.T. h m s	App. α h m s	No. Threads	C−O s	No.	Date 1899	Wash. M.T. h m s	App. α h m s	No. Threads	C−O s
1	Sept. 11.6	14 7 39	1 31 58.31	11	−1.65	16	Oct. 9.5	12 4 9	1 18 31.68	11	−2.41
2	12.6	14 3 38	1 31 52.96	11	−1.79	17	14.5	11 40 36	1 14 37.40	11	−2.46
3	14.6	13 55 29	1 31 36.03	8	−1.75	18	19.5	11 17 4	1 10 44.56	11	−2.41
4	15.6	13 51 22	1 31 24.70	11	−1.81	19	20.5	11 12 23	1 9 59.31	11	−2.44
5	21.6	13 25 59	1 29 36.42	11	−1.97	20	22.5	11 3 3	1 8 30.82	11	−2.43
6	22.6	13 21 38	1 29 11.94	11	−2.02	21	24.5	10 53 47	1 7 5.72	11	−2.41
7	24.6	13 12 52	1 28 17.59	11	−2.04	22	Nov. 1.4	10 17 28	1 2 13.75	11	−2.23
8	26.5	13 4 0	1 27 16.57	11	−2.12	23	4.4	10 4 17	1 0 50.13	11	−2.13
9	27.5	12 59 31	1 26 13.65	11	−2.15	24	5.4	9 59 57	1 0 25.92	11	−2.08
10	29.5	12 50 29	1 25 33.28	11	−2.21	25	9.4	9 42 57	0 59 9.15	11	−2.08
11	30.5	12 45 56	1 24 55.96	11	−2.22	26	12.4	9 30 33	0 58 33.29	11	−1.88
12	Oct. 1.5	12 41 21	1 24 17.31	11	−2.24	27	19.4	9 2 55	0 58 25.98	11	−1.71
13	2.5	12 36 46	1 23 37.55	11	−2.31	28	Dec. 16.3	7 32 25	1 14 8.24	11	−1.02
14	3.5	12 32 9	1 22 56.55	11	−2.31	29	20.3	7 20 56	1 18 23.37	11	−0.92
15	6.5	12 18 13	1 20 47.55	11	−2.33	30	26.3	7 4 27	1 25 31.52	13	−0.69

THE BENJAMIN APTHORP GOULD FUND.

Since making appropriations, in March 1899, of $500 to Prof. CHARLES L. DOOLITTLE, and of $300 to Mr. HENRY M. PARKHURST, from the BENJAMIN APTHORP GOULD FUND, a considerable additional amount of income has accrued, for the distribution of which the Directors are prepared immediately to arrange. Applications for appropriations may be made by letter to any of the undersigned, stating the amount desired, the nature of the proposed investigation, and the manner in which the appropriation is to be expended. Full information with regard to the Fund may be found in the announcement pertaining thereto in *A.J.* 453, a copy of which will be mailed, on request, to assist in framing applications. LEWIS BOSS, SETH C. CHANDLER, ASAPH HALL, *Directors*.

CONTENTS.

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DOUBLE-STAR MEASURES.

MADE AT THE LOWELL OBSERVATORY,

By W. A. COGSHALL.

The following double-star measures were made with the 24-inch telescope in the fall and winter of 1898. They are from a list furnished by Professor S. W. Burnham, at whose request they were measured. Those observations followed by "B" were made by Mr. S. L. Boothroyd; those followed by "C," by myself.

Because of much bad weather and other circumstances, some of the stars have been measured only on one and two nights. These I have included for the sake of completeness, hoping that in some cases at least they may become useful.

With few exceptions each measured angle is a mean of four readings of the micrometer, and the distance a mean of three double-distance readings, the line joining the observer's eyes being in all cases either parallel or perpendicular to the line joining the stars. On each night an estimate of the magnitudes was made, and in these measures the means of these estimates are given.

The places are those furnished by Mr. Burnham, and are for 1880.0.

β 131 (7.3 ; 10 ; 12.2).

$\alpha = 18^h\,6^m\,42^s$; $\delta = -15°\,38'$

AB

t	θ	ρ	
	°	″	
1898.625	278.5	2.60	
.636	280.1	2.91	
.644	279.6	2.90	
1898.635	279.4	2.80	

AC

t	θ	ρ	
1898.625	283.9	. .	
.636	283.9	7.49	
.644	283.2	7.31	
1898.635	283.7	7.40	C

Haze stopped measure on first night.

β 286 (6.2 ; 13.2).

$\alpha = 18^h\,8^m\,4^s$; $\delta = -20°\,25'$

t	θ	ρ	
1898.636	214.6	6.32	
.668	213.4	5.65	
.673	212.1	5.82	
1898.659	213.5	5.93	B

β 281 (7.3 ; 11).

$\alpha = 18^h\,9^m\,13^s$; $\delta = -19°\,2'$

AB

t	θ	ρ	
1898.666	359.1	. .	
.668	359.4	17.99	
.673	359.1	17.64	
.684	. .	17.90	
1898.673	359.3	17.84	

AC (C = 10.8)

t	θ	ρ	
	°	″	
1898.666	86.1	. .	
.668	86.6	30.95	
.673	86.7	30.41	
.684	. .	27.90	
1898.673	86.6	29.75	

Ab (b = 10.8)

t	θ	ρ	
1898.666	65.8	. .	
.668	65.9	21.77	
.673	66.5	21.96	
.684	. .	21.15	
1898.673	66.1	21.63	

Aa (a = 11.5)

t	θ	ρ	
1898.666	201.0	. .	
.668	198.9	12.00	
.673	198.8	11.88	
.684	. .	11.60	
1898.673	199.6	11.83	

Ad (d = 13.5)

t	θ	ρ	
1898.666	103.3	. .	
.668	102.1	. .	
.673	103.3	17.53	
1898.669	102.9	17.53	

Component d not noted by β.

Bc (c = 11.5)

t	θ	ρ	
	°	″	
1898.666	328.4	. .	
.668	327.4	5.28	
.673	325.8	4.80	
.684	. .	5.00	
1898.673	327.2	5.03	C

β 285 (8.2 ; 10.7 ; 9 ; 11.7).

$\alpha = 18^h\,9^m\,26^s$; $\delta = -25°\,3'$

AB

t	θ	ρ	
1898.671	319.6	1.51	
.689	317.1	. .	
1898.680	318.3	1.51	

AC

t	θ	ρ	
1898.671	140.8	59.50	
.689	140.2	60.02	
1898.680	140.5	59.76	

CD

t	θ	ρ	
1898.671	20.6	2.32	
.689	17.1	. .	
1898.680	18.8	2.32	B

β 246 (8 ; 8.5).

$\alpha = 18^h\,10^m\,34^s$; $\delta = -19°\,43'$

t	θ	ρ	
1898.671	107.9	0.51	C

β 18 (8 ; 10.7).

$\alpha = 18^h\,13^m\,55^s$; $\delta = -19°\,14'$.

t	θ	ρ	
	°	″	
1898.675	3.7	1.90	
.742	2.2	2.49	
.755	1.6	2.38	
1898.724	2.5	2.26	B

β 966 (7 ; 9.7 ; 10.2).

$\alpha = 18^h\,25^m\,25^s$; $\delta = -19°\,3'$

AB

1898.742	252.9	66.89	
.755	252.5	66.38	
.758	252.7	66.60	
1898.752	252.7	66.62	C

BC

1898.742	122.6	0.76	
.755	123.5	0.71	
.758	113.2	0.67	
.760	122.6	0.75	
1898.754	120.5	0.72	C

β 967 (8.2 ; 12.5).

$\alpha = 18^h\,34^m\,5^s$; $\delta = -14°\,37'$

1898.725	196.7	2.45	
.728	200.6	2.26	
.731	197.7	2.59	
1898.728	198.3	2.43	B

β 969 (7.2 ; 11.5).

$\alpha = 18^h\,43^m\,49^s$; $\delta = -8°\,3'$

1898.689	237.1	14.22	
.703	238.6	13.96	
.725	237.0	14.61	
1898.706	237.6	14.26	C

β 970 (8.5 ; 11.7).

$\alpha = 18^h\,44^m\,15^s$; $\delta = -8°\,8'$

1898.714	104.2	1.47	
.728	106.1	1.48	
.731	110.0	1.36	
1898.724	106.8	1.44	G

β 265 (7.8 ; 9.8).

$\alpha = 18^h\,44^m\,38^s$; $\delta = +11°\,23'$

1898.711	234.2	1.53	
.714	233.3	1.07	
.725	237.5	1.15	
1898.717	235.0	1.25	B

β 973 (8.3 ; 12.5 ; 11.8 ; 12.2).

$\alpha = 18^h\,55^m\,59^s$; $\delta = +8°\,34'$

AB

1898.731	346.5	1.74	
.733	353.4	1.64	
.739	350.5	1.78	
1898.734	350.1	1.72	

AC

t	θ	ρ	
	°	″	
1898.731	*[11.3]	10.92	
.733	20.1	11.21	
.739	21.4	11.16	
1898.734	20.7	11.10	

* Circle probably read wrong 10°.

AD = Σ 2435

1898.731	3.0	9.72	
.733	4.3	10.18	
.739	5.3	10.30	
1898.734	4.2	10.07	

CD

1898.731	261.6	3.91	
.733	261.8	3.57	
.739	260.2	3.82	
1898.734	261.2	3.77	B

β 974 (8.2 ; 9.8).

$\alpha = 18^h\,58^m\,53^s$; $\delta = -6°\,21'$

1898.671	88.9	0.91	
.701	85.7	0.91	
.703	88.0	0.91	
1898.692	87.5	0.91	B

β 56 (8.2 ; 9.5).

$\alpha = 19^h\,58^m\,47^s$; $\delta = -4°\,39'$

1898.613	166.9	1.67	
.625	166.0	1.57	
.666	165.4	1.42	
1898.635	166.1	1.55	B

β 832 (8.7 ; 9.7).

$\alpha = 20^h\,0^m\,5^s$; $\delta = -10°\,59'$

1898.666	101.5	2.25	
.671	106.9	1.55	
.701	104.2	1.61	
1898.679	104.2	1.80	C

β 833 (8 ; 8.5 ; 12 ; 12.7).

$\alpha = 20^h\,5^m\,11^s$; $\delta = -6°\,30'$

AB

1898.701	62.9	123.00	
.725	63.2	119.92	
.744	63.2	119.06	
1898.723	63.1	120.66	

AD (*D* = Boothroyd)

1898.701	357.1	43.79	
.725	357.6	43.70	
.744	356.9	43.39	
1898.723	357.2	43.63	

BC

1898.701	63.6	1.51	
.725	58.8	2.08	
.744	60.0	2.28	
.742	61.5	2.64	
1898.733	61.1	2.30	B

β 662 (9 ; 11.7).

$\alpha = 20^h\,14^m\,0^s$; $\delta = -19°\,59'$

t	θ	ρ	
	°	″	
1898.711	301.8	1.42	
.755	298.3	1.66	
.758	302.1	1.76	
1898.741	300.6	1.61	C

β 672 (6 ; 12).

$\alpha = 20^h\,32^m\,8^s$; $\delta = -1°\,31'$

1898.613	281.5	31.48	
.622	281.2	31.47	
.625	280.7	31.68	
1898.620	281.1	31.54	C

β 1209 (9 ; 10.5).

$\alpha = 20^h\,34^m\,9^s$; $\delta = -17°\,48'$

1898.733	282.2	0.64	
.744	280.2	0.61	
1898.739	281.2	0.63	C

β 267 (9 ; 9.5).

$\alpha = 20^h\,35^m\,25^s$; $\delta = -4°\,50'$

1898.636	242.2	2.04	
.666	239.9	1.88	
.668	237.5	2.17	
1898.657	239.9	2.03	B

β 674 (7.2 ; 9.7).

$\alpha = 20^h\,37^m\,53^s$; $\delta = -21°\,19'$

1898.622	101.6	1.59	
.666	103.4	1.48	
.711	103.3	1.71	
1898.666	102.8	1.59	C

β 764 (8.7 ; 8.7).

$\alpha = 20^h\,52^m\,22^s$; $\delta = -9°\,50'$

AB

1898.744	361.0	0.85	
.755	355.6	0.86	
.758	360.5	0.87	
1898.752	359.0	0.86	B

AC (*C* = 8.4)

1898.744	112.3	100.41	
.755	111.7	100.23	
.758	112.0	100.39	
1898.752	112.0	100.34	

AD (*D* = 8.2)

1898.744	21.8	137.33	
.755	21.4	138.46	
.758	21.6	137.62	
1898.752	21.6	137.80	

AE (*E* = 11.5, Boothroyd)

1898.744	89.9	58.75	
.755	89.7	59.48	
.758	89.5	59.02	
1898.752	89.7	59.08	

DF (F = 13.5, Boothroyd)

t	θ	ρ	
	°	″	
1898.744	193.6	24.82	
.755	193.1	24.51	
.758	193.6	24.35	
1898.752	193.4	24.56	

There is another companion to C in 180°± 50″±, Mag. 14. Also two more to D as follows:

(1)	150° ±	45″ ±	Mag. 14
(2)	80 ±	40 ±	14

B

β 765 (7 ; 12.5).

$\alpha = 20^h\,53^m\,9^s$; $\delta = -35°\,45'$

1898.733	140.7	2.32	B

β 473 (8.2 ; 9.7 ; 12.7).

$\alpha = 21^h\,1^m\,23^s$; $\delta = -10°\,41'$

AB

1898.625	116.0	1.76	
.668	120.2	1.91	
.671	117.7	1.80	
1898.655	118.0	1.82	

AC (C = Cogshall)

1898.668	357.1	25.05	
.671	357.4	25.70	
1898.669	357.2	25.37	C

β 1035 (8.5 ; 11).

$\alpha = 21^h\,17^m\,16^s$; $\delta = -26°\,4'$

1898.725	205.6	1.21	C

β 447 (6.3 ; 13).

$\alpha = 21^h\,18^m\,46^s$; $\delta = +24°\,48'$

1898.613	329.6	8.86	
.625	328.2	8.77	
.666	332.8	8.60	
1898.635	330.2	8.74	B

β 767 (6.5 ; 11.5).

$\alpha = 21^h\,19^m\,19^s$; $\delta = -43°\,4'$

1898.701	145.8	3.03	
.733	145.4	3.11	
1898.717	145.6	3.07	C

β 683 (8.2 ; 12).

$\alpha = 21^h\,20^m\,43^s$; $\delta = -20°\,44'$

1898.668	194.3	2.72	
.722	194.9	2.62	
1898.695	194.6	2.67	B

β 73 (3.7 ; 10.5 ; 11.2).

$\alpha = 21^h\,25^m\,14^s$; $\delta = -6°\,6'$

AB

1898.622	318.4	34.99	
.625	318.5	34.72	
.636	318.2	35.18	
1898.628	318.4	34.96	

AC

t	θ	ρ	
	°	″	
1898.622	185.3	55.63	
.625	184.2	56.32	
.636	184.4	55.95	
1898.628	184.6	55.97	C

β 693 (7.2 ; 11.5).

$\alpha = 21^h\,49^m\,54^s$; $\delta = -7°\,33'$

1898.622	53.3	1.19	
.660	50.2	1.38	
.666	50.3	1.05	
1898.649	51.3	1.21	C

β 171 (8 ; 11.2).

$\alpha = 22^h\,7^m\,51^s$; $\delta = -21°\,38'$

1898.622	258.0	11.75	
.668	258.6	11.44	
.675	257.7	11.29	
1898.655	258.1	11.49	C

β 178 (8.5 ; 10.2).

$\alpha = 22^h\,23^m\,8^s$; $\delta = -7°\,56'$

AB

1898.668	30.1	. .	
.742	31.1	1.66	
.758	30.2	1.58	
1898.723	30.6	1.62	

AC (C = 8.7)

1898.668	238.9	28.47	
.742	239.8	28.91	
.758	239.6	28.68	
1898.725	239.4	28.69	

AD (D = 13.5, Boothroyd)

1898.668	58.1	18.78	
.758	51.3	19.06	
1898.713	54.7	18.92	

AE (E = 13.5, not measured by β)

1898.668	20.8	[40. ±]	
.758	17.3	31.11	
1898.713	19.1	31.11	B

β 76 (8 ; 9.7).

$\alpha = 22^h\,23^m\,23^s$; $\delta = -0°\,49'$

1898.641	337.4	1.52	
.660	338.0	1.47	
.666	335.8	1.38	
1898.656	337.1	1.46	B

β 770 (8 ; 12).

$\alpha = 22^h\,27^m\,47^s$; $\delta = -23°\,13'$

1898.660	348.5	1.43	C

β 77 (8 ; 8.5 ; 10).

$\alpha = 22^h\,27^m\,51^s$; $\delta = -2°\,24'$

AB

t	θ	ρ	
	°	″	
1898.625	211.9	2.68	
.636	216.1	2.74	
1898.630	214.0	2.71	

AC

1898.625	225.2	28.61	
.636	225.1	28.06	
1898.630	225.1	28.33	B

β 709 (8 ; 8.7).

$\alpha = 22^h\,35^m\,26^s$; $\delta = -5°\,11'$

1898.622	5.8	1.98	
.641	5.2	2.06	
.663	7.1	1.92	
1898.642	6.0	1.99	C

β 177 (8 ; 8.1).

$\alpha = 22^h\,45^m\,55^s$; $\delta = -22°\,21'$

1898.660	275.5	2.79	
.673	279.1	2.86	
.722	274.6	2.71	
1898.685	276.4	2.79	B

β 178 (6.5 ; 9).

$\alpha = 22^h\,48^m\,57^s$; $\delta = -5°\,58'$

1898.663	324.5	0.79	C

β 772 (3.8 ; 11).

$\alpha = 22^h\,49^m\,18^s$; $\delta = -35°\,11'$

1898.625	239.4	5.36	
.630	235.6	4.76	
.663	235.8	5.50	
1898.639	236.9	5.21	C

β 1011 (7 ; 11).

$\alpha = 22^h\,55^m\,53^s$; $\delta = -37°\,4'$

1898.733	297.4	2.14	B

β 384 (7.7 ; 9.5).

$\alpha = 22^h\,56^m\,14^s$; $\delta = -19°\,10'$

1898.630	66.9	1.43	
.733	66.5	1.22	
1898.681	66.7	1.32	B

β 481 (9.7 ; 10).

$\alpha = 22^h\,56^m\,2^s$; $\delta = -11°\,8'$

1898.673	53.5	1.40	
.733	54.2	1.40	
.867	47.3	1.12	
1898.758	51.7	1.34	C

β 715 (6.8 ; 13.2).

$\alpha = 23^h\ 8^m\ 25^s$; $\delta = -11°\ 20'$

t	θ	ρ	
	°	″	
1898.641	252.5	3.45	
.684	259.4	3.44	
.758	259.7	3.65	
1898.694	257.2	3.51	B

β 716 (9 ; 11.5).

$\alpha = 23^h\ 9^m\ 15^s$; $\delta = -9°\ 43'$

1898.763	207.6	1.63	
.862	208.2	1.08	
1898.812	207.9	1.35	C

β 387 (8.2 ; 9.2).

$\alpha = 23^h\ 28^m\ 8^s$; $\delta = -10°\ 22'$

1898.625	70.1	5.98	
.666	70.1	5.89	
.673	69.7	5.85	
1898.654	70.0	5.91	B

β 721 (8 ; 8.5 ; 12.5).

$\alpha = 23^h\ 30^m\ 7^s$; $\delta = -7°\ 47'$

AB

1898.681	117.1	0.73	B

$\frac{AB}{2}$. C (C = Boothroyd)

1898.681	301.7	21.38	B

β 775 (7 ; 11).

$\alpha = 23^h\ 30^m\ 45^s$; $\delta = -32°\ 32'$

1898.684	252.5	5.53	
.701	250.5	5.04	
.711	250.7	5.26	
1898.699	251.2	5.28	C

β 724 (9 ; 10).

$\alpha = 23^h\ 34^m\ 46^s$; $\delta = +7°\ 18'$

1898.681	91.2	0.86	
.758	88.2	0.72	
.763	88.0	0.77	
1898.734	89.1	0.78	C

β 279 (4.5 ; 10.7).

$\alpha = 23^h\ 36^m\ 30^s$; $\delta = -15°\ 12'$

1898.625	83.5	5.12	
.663	83.8	5.45	
.671	84.5	5.38	
1898.653	83.9	5.32	C

β 726 (8.5 ; 10.5).

$\alpha = 23^h\ 40^m\ 23^s$; $\delta = -13°\ 25'$

1898.758	326.3	0.89	B

β 1013 (5.7 ; 6 ; 8).

$\alpha = 23^h\ 42^m\ 40^s$; $\delta = -28°\ 48'$

AC

1898.722	296.8	74.06	
.758	296.7	74.41	
1898.740	296.7	74.23	

AB

t	θ	ρ	
	°	″	
1898.722	254.0	1.07	B

β 730 (6 ; 11.7).

$\alpha = 23^h\ 52^m\ 32^s$; $\delta = -4°\ 13'$

1898.641	271.0	1.58	
.663	271.2	1.72	
.673	273.3	1.69	
1898.659	272.8	1.66	C

β 731 (8.5 ; 9.2).

$\alpha = 23^h\ 53^m\ 27^s$; $\delta = -8°\ 28'$

1898.663	265.6	1.69	
.742	265.6	1.54	
.758	266.2	1.57	
1898.721	265.8	1.60	C

β 391 (7 ; 7.2).

$\alpha = 0^h\ 3^m\ 14^s$; $\delta = -28°\ 39'$

1898.681	273.5	1.01	
.711	266.6	1.18	
1898.696	270.0	1.09	B

β 998 (8.8 ; 9).

$\alpha = 0^h\ 7^m\ 30^s$; $\delta = +5°\ 55'$

1898.660	116.5	1.26	
.711	115.7	1.40	
.722	113.6	1.50	
1898.698	115.3	1.39	C

β 486 (6 ; 12).

$\alpha = 0^h\ 8^m\ 19^s$; $\delta = -8°\ 27'$

1898.625	8.0	3.00	
.733	9.7	3.26	
1898.679	8.8	3.13	B
1898.780	2.9	3.03	C

β 393 (7.5 ; 9).

$\alpha = 0^h\ 12^m\ 12^s$; $\delta = -21°\ 48'$

1898.689	12.7	0.69	C

β 256 (9 ; 9.2).

$\alpha = 0^h\ 13^m\ 53^s$; $\delta = -14°\ 30'$

1898.722	251.7	2.51	B

β 1093 (7.5 ; 8.2).

$\alpha = 0^h\ 14^m\ 44^s$; $\delta = +10°\ 19'$

1898.681	46.2	0.52	
.711	62.7	0.75	
.742	57.6	0.72	
1898.711	55.5	0.66	B

β 777 (8.2 ; 8.8).

$\alpha = 0^h\ 14^m\ 56^s$; $\delta = -0°\ 55'$

1898.673	167.8	3.95	
.698	166.3	3.94	
.714	166.9	3.77	
1898.695	167.0	3.89	B

β 488 (7.4 ; 10.6).

$\alpha = 0^h\ 17^m\ 52^s$; $\delta = -4°\ 8'$

t	θ	ρ	
	°	″	
1898.625	347.3	3.01	
.663	346.8	3.18	
.698	347.8	3.10	
.856	344.7	3.01	
1898.710	346.7	3.07	C

β 109 (6.8 ; 10.2 ; 10.9).

$\alpha = 0^h\ 34^m\ 27^s$; $\delta = -17°\ 10'$

AB

1898.673	355.9	[92.21]	
.714	354.3	102.61	
.733	354.7	103.19	
.906	354.9	103.36	
.911	354.4	103.04	
1898.787	354.8	103.05	C
1898.911	. .	102.82*	

* D. A. Drew.

BC

1898.673	160.5	11.32	
.714	161.2	11.11	
.733	160.0	11.28	
.906	160.6	11.30	
.911	160.3	11.20	
1898.787	160.5	11.24	C

β 494 (8.2 ; 8.3).

$\alpha = 0^h\ 40^m\ 53^s$; $\delta = -1°\ 54'$

1898.625	172.3	1.26	
.660	173.6	1.31	
.663	170.1	1.42	
1898.649	172.0	1.33	B

β 234 (8.2 ; 8.3 ; 8.6).

$\alpha = 0^h\ 54^m\ 36^s$; $\delta = -17°\ 43'$

AB

1898.663	331.7	4.68	
.698	331.7	4.47	
.742	332.1	4.61	
1898.701	331.8	4.58	

AC

1898.663	132.7	63.26	
.698	131.5	60.28	
.742	131.9	63.47	
1898.701	132.0	62.34	C

β 501 (7.2 ; 11.8).

$\alpha = 1^h\ 0^m\ 40^s$; $\delta = -5°\ 17'$

1898.625	28.6	2.63	
.644	27.7	2.83	
.660	28.9	2.94	
1898.643	28.4	2.80	C

β 399 (6.4 ; 9.2).

$\alpha = 1^h\,21^m\,48^s$; $\delta = -11°\,31'$

t	θ	ρ	
	°	″	
1898.625	304.1	1.69	
.660	300.0	1.67	
.663	300.9	1.61	
1898.649	301.7	1.66	B

β 1230 (6.6 ; 12.2).

$\alpha = 1^h\,24^m\,43^s$: $\delta = -26°\,50'$

1898.644	225.8	2.86	
.660	223.9	2.86	
.763	227.9	2.99	
1898.689	225.9	2.90	C

β 869 (8 ; 12).

$\alpha = 1^h\,30^m\,3^s$: $\delta = +3°\,42'$

1898.698	195.5	5.15	
.742	197.9	5.35	
.911	196.4	5.26	
1898.784	196.6	5.25	B

β 871 (8 ; 9).

$\alpha = 1^h\,41^m\,49^s$; $\delta = -1°\,33'$

1898.644	351.5	1.99	
.698	352.4	2.06	
.711	353.1	2.19	
1898.684	352.3	2.08	C

β 1168 (8 ; 9).

$\alpha = 1^h\,43^m\,48^s$; $\delta = -10°\,58'$

1899.000	202.0	0.72	B

β 511 (8 ; 8.3 ; 13.2).

$\alpha = 1^h\,42^m\,40^s$; $\delta = -2°\,1'$

	AB		
1898.711	159.7	30.28	
.714	160.4	30.43	
.742	160.2	30.49	
1898.722	160.1	30.40	
	BC		
1898.711	315.1	4.21	
.714	316.5	4.05	
.742	314.0	4.07	
1898.722	315.2	4.11	B

β 1001 (8.2 ; 12.7)

$\alpha = 1^h\,43^m\,5^s$; $\delta = -18°\,59'$

1898.791	8.8	1.14	
1899.000	3.1	0.81	
1898.895	6.0	0.97	C

β 259 (7.7 ; 9.8).

$\alpha = 1^h\,46^m\,20^s$; $\delta = -10°\,19'$

1898.663	237.4	1.35	
.681	237.8	4.58	
.722	238.1	4.74	
1898.689	237.8	4.56	C

β 183 (8.0 ; 8.5).

$\alpha = 1^h\,47^m\,21^s$; $\delta = -17°\,20'$

t	θ	ρ	
	°	″	
1898.709	227.9	2.50	
.911	229.4	2.66	
.925	230.3	2.65	
1898.848	229.2	2.60	B

β 511 (8 ; 10.5).

$\alpha = 1^h\,53^m\,57^s$: $\delta = -13°\,54'$

1898.681	133.4	6.39	
.911	133.1	6.18	
.925	132.6	6.35	
1898.839	133.0	6.31	B

β 516 (8.8 ; 8.8).

$\alpha = 1^h\,59^m\,6^s$; $\delta = -1°\,33'$

1898.641	289.8	0.94	
.709	289.8	0.90	
.742	288.6	0.87	
1898.698	289.4	0.90	C

β 8 (7.8 ; 9).

$\alpha = 2^h\,14^m\,59^s$: $\delta = +8°\,20'$

1898.644	206.3	1.38	
.791	208.4	1.42	
.911	206.8	1.32	
1898.782	207.2	1.37	C

β 738 (7 ; 8).

$\alpha = 2^h\,18^m\,0^s$; $\delta = -30°\,25'$

1899.000	184.1	0.79	B

β 517 (6.5 ; 9.5 ; 9.5).

$\alpha = 2^h\,18^m\,54^s$: $\delta = -4°\,26'$

	AB		
1898.911	248.4	11.37	
	AC		
1898.911	289.2	56.11	B

β 519 (8.5 ; 9.3).

$\alpha = 2^h\,23^m\,38^s$: $\delta = -2°\,48'$

1898.742	60.9	1.05	
.985	54.5	0.85	
1899.000	57.1	0.89	
1898.909	57.5	0.93	B

β 520 (8.5 ; 10.5).

$\alpha = 2^h\,30^m\,49^s$, $\delta = -4°\,6'$

1898.709	209.0	0.92	
.925	205.0	0.84	
1898.817	207.0	0.88	B

β 261 (7.6 ; 9.4).

$\alpha = 2^h\,38^m\,31^s$: $\delta = -28°\,2$[illegible]

t	θ	ρ	
	°	″	
1898.644	99.6	2.92	
.791	99.9	3.02	
.832	100.0	2.67	
.835	101.0	2.92	
1898.775	100.1	2.88	C

β 1002 (7.8 ; 12.7).

$\alpha = 2^h\,41^m\,30^s$; $\delta = -15°\,53'$

1898.791	333.7	1.82	
.832	332.5	1.43	
1899.000	334.6	1.44	
1898.874	333.6	1.56	C

β 877 (6.5 ; 11.8 ; 10.7).

$\alpha = 2^h\,44^m\,32^s$: $\delta = -25°$ [illegible]

	AB		
1898.835	144.6	11.54	
.985	142.1	11.78	
1899.000	144.4	11.74	
1898.940	143.7	11.69	
	AC		
1898.835	154.1	46.69	
.985	152.2	47.01	
1899.000	153.7	46.43	
1898.940	153.3	46.71	B

β 11 (6.2 ; 11.3).

$\alpha = 2^h\,56^m\,49^s$: $\delta = -8°\,9'$

1898.660	84.4	2.57	
.911	82.7	2.61	
.925	84.4	2.06	
1898.832	83.8	2.41	C

β 527 (8.2 ; 8.2).

$\alpha = 3^h\,0^m\,35^s$: $\delta = -13°\,45'$

1898.709	66.2	0.82	
.931	66.8	0.73	
1899.014	62.9	0.87	
1898.885	65.3	0.81	B

β 528 (8.8 ; 8.8).

$\alpha = 3^h\,2^m\,25^s$: $\delta = -4°\,3'$

1898.709	198.5	0.87	
.832	196.4	1.01	
.931	198.0	0.93	
1898.824	197.6	0.95	C

β 529 (7.5 ; 13.7).

$\alpha = 3^h\,8^m\,9^s$; $\delta = -9°\,1'$

1898.791	222.3	3.29	
.832	219.3	. .	
.835	220.6	3.71	
1898.819	220.7	3.50	C

β 12 (7.3 ; 9.7).

$\alpha = 3^h\,18^m\,47^s$; $\delta = -14°\,25'$

t	θ	ρ	
	°	″	
1898.709	271.3	2.14	
.911	274.9	2.06	
.925	270.9	2.22	
1898.848	272.4	2.14	B

β 532 (8.2 ; 13.7).

$\alpha = 3^h\,27^m\,25^s$; $\delta = -10°\,27'$

1898.791	271.3	2.99	
.911	271.1	2.98	
.925	272.8	. .	
.931	270.2	[3.±]	
1898.889	271.1	2.99	C

β 534 (8 ; 12.5).

$\alpha = 3^h\,33^m\,1^s$; $\delta = -8°\,54'$

1898.835	194.9	2.55	
.911	193.4	2.77	
1898.873	194.1	2.66	B

β 308 (8.7 ; 10.1).

$\alpha = 3^h\,32^m\,5^s$; $\delta = -8°\,3'$

1898.832	330.3	1.77	
.835	330.1	1.92	
.911	332.1	1.96	
1898.859	330.8	1.88	C

β 1003 (8 ; 13.2).

$\alpha = 3^h\,40^m\,25^s$; $\delta = -28°\,15'$

1898.931	34.1	2.73	
1899.014	34.7	2.79	
1898.972	34.4	2.76	B

β 542 (8.3 ; 10.2).

$\alpha = 3^h\,50^m\,21^s$; $\delta = -7°\,18'$

1898.791	192.4	1.79	
.925	193.5	1.12	
.931	191.7	1.59	
1898.882	192.5	1.50	C

β 543 (7.7 ; 11).

$\alpha = 3^h\,51^m\,25^s$; $\delta = -1°\,30'$

1898.832	26.7	10.95	
.835	26.8	11.14	
.911	27.0	10.91	
1898.859	26.8	11.00	C

β 548 (7.5 ; 11.7).

$\alpha = 4^h\,10^m\,58^s$; $\delta = -10°\,23'$

1898.742	347.0	6.02	
.835	342.2	6.13	
.925	346.4	6.27	
1898.834	345.2	6.14	C

β 744 (7.5 ; 8).

$\alpha = 4^h\,16^m\,32^s$; $\delta = -26°\,1'$

AB

t	θ	ρ	
	°	″	
1898.931	307.3	0.80	

$AC = H\,3644$ ($C = 11$)

1898.931	7.2	35.80	

AD ($D = 9$)

1898.931	40.8	44.88	B

β 402 (8.2 ; 11.5 ; 13.5).

$\alpha = 4^h\,17^m\,3^s$; $\delta = -1°\,33'$

AB

1898.832	73.3	7.21	
.925	69.4	7.27	
.985	70.1	7.36	
1898.914	70.9	7.28	

AC (C = Cogshall)

1898.925	110.±	7.80	C

β 403 (7.3 ; 9.5).

$\alpha = 4^h\,19^m\,18^s$; $\delta = -2°\,20'$

1898.742	100.3	2.01	
.835	97.5	2.13	
.985	98.0	1.73	
1898.854	98.6	1.96	C

β 311 (7.5 ; 7.5).

$\alpha = 4^h\,21^m\,52^s$; $\delta = -24°\,21'$

1898.742	336.5	0.92	
1899.014	328.2	0.79	
1898.878	332.3	0.85	C

β 549 (7.2 ; 12).

$\alpha = 4^h\,23^m\,2^s$; $\delta = -12°\,13'$

1898.832	188.7	8.48	
.931	186.6	8.65	
.985	185.1	8.44	
1898.916	186.8	8.52	C

β 881 (6 ; 9.5).

$\alpha = 4^h\,29^m\,4^s$; $\delta = -7°\,0'$

1898.742	52.4	1.94	C

β 882 (8.2 ; 9.7).

$\alpha = 4^h\,32^m\,14^s$; $\delta = -11°\,23'$

1898.835	224.5	2.70	
.985	255.5	2.75	
1898.910	240.0	2.72	B

β 186 (8 ; 9.5).

$\alpha = 4^h\,40^m\,10^s$; $\delta = -7°\,12'$

t	θ	ρ	
	°	″	
1898.835	183.0	1.70	
.931	177.8	1.52	
.985	184.1	1.72	
1898.917	181.6	1.65	B

β 312 (7.7 ; 8.5).

$\alpha = 4^h\,42^m\,36^s$; $\delta = -21°\,1'$

1898.835	343.6	3.56	
.931	345.4	3.30	
1898.883	344.5	3.43	B
1898.843	345.2	3.05	C

β 748 (8 ; 8.5).

$\alpha = 4^h\,47^m\,14^s$; $\delta = -7°\,53'$

1898.931	130.9	1.20	C

β 318 (8.5 ; 8.5).

$\alpha = 5^h\,10^m\,15^s$; $\delta = -3°\,37'$

1898.843	227.0	0.79	
1899.011	232.8	0.77	
1898.927	229.9	0.78	C

β 189 (7.2 ; 11).

$\alpha = 5^h\,14^m\,33^s$; $\delta = -5°\,28'$

1898.835	288.8	4.48	
.931	284.0	4.31	
.985	287.5	4.41	
1898.917	286.8	4.40	B

β 89 (8 ; 10.2).

$\alpha = 5^h\,31^m\,29^s$; $\delta = -1°\,30'$

1898.835	1.4	1.04	
.985	2.1	0.85	
1898.910	1.7	0.95	C

β 322 (8 ; 9).

$\alpha = 5^h\,34^m\,40^s$; $\delta = -25°\,13'$

1898.835	103.0	2.87	B

β 15 (7.5 ; 11).

$\alpha = 5^h\,41^m\,45^s$; $\delta = -2°\,20'$

1898.843	178.7	2.05	C

β 94 (6.5 ; 9).

$\alpha = 5^h\,44^m\,9^s$; $\delta = -14°\,31'$

1898.843	180.1	2.56	C

β 16 (6 ; 10).

$\alpha = 5^h\,56^m\,12^s$; $\delta = -10°\,36'$

1898.835	351.5	1.82	B

OBSERVATIONS OF COMET *e* 1899 V,

MADE AT THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA.

By C. D. PERRINE.

1899 Mt. Hamilton M.T.	*	No. Comp.	☌′ − * Δα	☌′ − * Δδ	☌′'s apparent α	☌′'s apparent δ	log pΔ for α	log pΔ for δ	Telescope
			m s	′ ″	h m s	° ′ ″			
Oct. 15 6 47 43	1	d10, 8	−0 3.30	+1 10.8	16 51 45.40	− 0 15 28.2	9.576	0.728	36
23 6 26 48	3	d10, 8	+0 14.00	+3 18.2	17 3 41.87	+ 1 59 17.3	9.574	0.715	12
24 6 38 28	5	d10, 8	+0 15.07	+1 58.3	17 5 13.56	+ 2 16 10.6	9.593	0.714	12
25 6 59 2	7	d10, 8	+0 13.49	−1 33.0	17 6 46.01	+ 2 32 51.2	9.620	0.715	12
26 6 52 43	9	d10, 8	+0 4.43	−2 24.3	17 8 17.12	+ 2 49 8.1	9.615	0.712	12
7 31 47	9	d10, 8	+0 6.90	−1 57.7	17 8 19.59	+ 2 49 34.7	9.648	0.718	12
30 7 14 8	11	d10, 8	+0 4.20	−0 1.1	17 14 27.21	+ 3 54 34.0	9.643	0.713	12
31 6 47 2	13	d10, 8	−0 29.55	−6 22.9	17 15 58.17	+ 4 10 11.1	9.622	0.707	12
Nov. 1 6 35 20	14	d10, 8	+0 1.20	−1 34.5	17 17 30.64	+ 4 26 7.2	9.613	0.702	12
6 6 16 49	15	d10, 8	−0 8.07	+8 4.2	17 25 19.52	+ 5 46 14.1	9.607	0.695	12
6 34 40	16	d10, 8	+0 37.84	+2 55.5	17 25 20.80	+ 5 46 21.7	9.626	0.699	12
20 6 13 30	17	d 6, 6	+0 10.77	−3 13.3	17 47 52.06	+ 9 31 22.3	9.639	0.680	12
23 6 30 3	18	d10, 8	−0 6.40	+0 54.7	17 52 50.51	+10 20 44.9	9.657	0.687	12
Dec. 1 6 18 52	20	d 8, 6	+0 4.44	−2 53.6	18 6 14.	+12 34.7	9.655	0.679	36
2 6 9 10	22	d 8, 6	+0 5.99	−0 9.1	18 7 54.79	+12 50 41.4	9.662	0.674	36
5 6 19 15	24	d 8, 6	−0 25.12	−2 12.0	18 13 2.59	+13 42 14.8	9.672	0.679	12
6 6 13 8	25	d10, 8	−0 22.57	−1 13.5	18 14 14.90	+13 59 26.5	9.670	0.676	12
9 6 1 35	26	d10, 8	+0 9.20	+1 7.8	18 19 53.89	+14 51 32.7	9.670	0.669	36
23 6 15 10	28	d10, 8	+0 1.05	−6 35.0	18 44 32.08	+19 6 29.3	9.695	0.686	36

Mean Places for 1899.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 51 46.11	+2.59	− 0 16 40.4	+1.4	12^M. Compared with *2
2	16 49 14.32	+2.58	− 0 22 31.5	+1.2	B.B. VI. −0°3200
3	17 3 25.38	+2.49	+ 1 55 56.3	+2.8	11^M. Compared with *4
4	17 1 54.98	+2.48	+ 1 55 45.2	+2.6	Boss. Albany A.G. 5651
5	17 4 56.01	+2.18	+ 2 14 9.4	+2.9	11^M. Compared with *6
6	17 7 16.33	+2.49	+ 2 14 49.3	+3.2	Boss. Albany A.G. 5688
7	17 6 30.05	+2.47	+ 2 34 21.2	+3.0	11^M. Compared with *8
8	17 5 6.67	+2.47	+ 2 37 22.1	+2.9	Boss, Albany A.G. 5675
9	17 8 10.23	+2.46	+ 2 51 29.2	+3.2	12^M. Compared with *10
10	17 7 11.32	+2.46	+ 2 48 59.4	+3.1	Boss, Albany A.G. 5687
11	17 11 20.61	+2.40	+ 3 54 31.5	+3.6	11^M. Compared with *12
12	17 16 10.81	+2.41	+ 3 55 34.6	+3.8	Boss, Albany A.G. 5741
13	17 16 25.33	+2.39	+ 4 16 30.2	+3.8	" " " 5744
14	17 17 27.07	+2.37	+ 4 27 37.8	+3.9	" " " 5753
15	17 25 25.25	+2.34	+ 5 38 5.3	+4.6	Bruns and Peter. Leipzig A.G., 7861
16	17 24 40.63	+2.33	+ 5 43 21.6	+4.6	" " " " " 7847
17	17 47 39.07	+2.22	+ 9 34 29.6	+6.0	" " " " " 8128
18	17 52 54.70	+2.21	+10 19 44.0	+6.2	10½^M. Compared with *19
19	17 54 54.91	+2.22	+10 18 8.3	+6.4	W. Bessel 1097
20	18 6 7	+2.13	+12 37.5	+6.8	12^M. Compared with *21. *Note*
21	18 6 3	+2.13	+12 40.1	+6.8	DM. +12°3415; 8^M.5
22	18 7 46.67	+2.13	+12 50 43.6	+6.9	11^M. Compared with *23
23	18 6 16.89	+2.13	+12 49 51.2	+6.7	W. Bessel 74
24	18 13 25.58	+2.13	+13 44 19.7	+7.1	Pulkowa 2571
25	18 15 5.34	+2.13	+14 0 32.8	+7.2	Rümker 6397
26	18 19 42.58	+2.11	+14 50 47.7	+7.2	13^M. Compared with *27
27	18 19 14.25	+2.11	+14 51 26.7	+7.1	Auwers, Berlin A.G. 6763
28	18 44 28.99	+2.04	+19 12 56.4	+7.9	" " " 7031

NOTES.

d inserted before the number of comparisons indicates that $\Delta\alpha$ was measured directly with the micrometer.

Oct. 15th, 12^M 13^M. — 23d 24th, 12^M, faint nucleus. — 25th 12^M, nucleus still visible. — 26th, Comet very faint, owing to haze. —30th, 12^M, 1′ diameter, central condensation. — 31st, $11\frac{1}{2}^M$ or 12^M, 1′ diameter, central condensation.— *Nov.* 1st, 12^M.—6th, 12^M, ½′ diameter, brighter at center.—20th, 13^M.—23d, 13^M, 1′ diameter.—*Dec.* 1st, 12^M, 1′ diameter; nebulosity more pronounced on southern side of nucleus; nucleus 14^M, and about as sharp as the stars; seeing 2. The observed distance between the comparison and catalogue stars was $\Delta\alpha$ +4ˢ.09 $\Delta\delta$ −2′ 33″.2 (comparison star—catalogue star).—5th, Comet faint, and near a 12^M star; seeing poor. — 6th, Comet faint. Comparison star is double, 0°, 3″, $8^M.5$ and 10^M. — 9th, 13^M, round, ¾′–1′ diameter. Faint nucleus. 23d, 13^M, 20″ diameter. Brighter at the center. Comet necessarily observed at large hour-angles.

Mt. Hamilton, California, 1900 *Feb.* 3.

OBSERVATIONS OF COMET *a* 1900 (GIACOBINI),

MADE AT THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA,

BY C. D. PERRINE.

1900 Mt. Hamilton M.T.	*	No. Comp.	☄ − * $\Delta\alpha$	☄ − * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Telescope
Feb. 16 7ʰ 51ᵐ 28ˢ	1	*d* 6 , 6	+0ᵐ 0ˢ.29	+8′ 4″.7	2ʰ 23ᵐ 3ˢ.61	−1° 33′ 6″.7	9.549	0.739	12
21 7 18 19	3	*d*10 , 8	+0 11.03	−3 28.2	2 15 50.47	+0 8 50.8	9.538	0.727	12
28 7 14 48	5	*d*10 , 8	+0 26.03	+5 56.8	2 7 32.06	+2 22 27.2	9.588	0.713	12

Mean Places for 1900.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	2ʰ 23ᵐ 2ˢ.27	+1ˢ.05	−1° 41′ 10″.9	−0″.5	Micrometer-comparison with *2
2	2 27 3.16	+1.07	−1 38 12.4	−0.6	½ (Göttingen 642 + Schjellerup 709)
3	2 15 38.50	+0.94	+0 12 19.0	0.0	Micrometer comparison with *4
4	2 10 1.51	+0.92	+0 15 15.2	+0.2	½ (Paris 2805 + Rad.₃ 522)
5	2 7 5.18	+0.85	+2 16 29.5	+0.9	Boss, Albany A.G. 616

In all three observations $\Delta\alpha$ was measured directly with the micrometer. The comet is nearly round, and has a faint nucleus of about the 13th magnitude. The light of the entire comet was estimated at 10½ or 11th magnitude. Diameter of comet 2′.

Mt. Hamilton, California, 1900 *March* 3.

ELEMENTS AND EPHEMERIS OF COMET *a* 1900 (GIACOBINI),

BY C. D. PERRINE.

From the Nice observation of Feb. 3, and my own observations of February 16 and 21, I derive the following elements:

T = 1900 April 29.0781 Gr. M.T.

$$\left.\begin{aligned}\omega &= 24^\circ\ 36'\ 56''.6\\ \Omega &= 40\ 24\ 38.8\\ i &= 146\ 25\ 22.2\end{aligned}\right\}\ 1900.0 \qquad \begin{aligned}&\text{O}-\text{C}:\\ \Delta\lambda'\cos\beta' &= -0''.4\\ \Delta\beta' &= +0''.1\end{aligned}$$

$\log q$ = 0.123476

The constants for the equator of 1900 are,

$$\begin{aligned}x &= r[9.970123]\ \sin(v + 79^\circ\ 15'\ 59''.5)\\ y &= r[9.999348]\ \sin(v + 168\ \ 3\ 35.9)\\ z &= r[9.559528]\ \sin(v + 69\ 57\ 41.8)\end{aligned}$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1900	True α	True δ	log Δ	Br.
Mar. 22.5	1ʰ 50ᵐ 32ˢ	+ 8° 27′.6	0.354	0.82
26.5	1 48 19	+ 9 28.8		
Mar. 30.5	1 46 15	+10 29.2	0.364	0.83
Apr. 3.5	44 18	11 28.9		
7.5	42 26	12 28.2	0.369	0.85
11.5	40 36	13 27.5		
15.5	38 47	14 27.0	0.370	0.87
19.5	36 56	15 27.0		
23.5	35 3	16 27.8	0.366	0.91
27.5	33 6	17 29.8		
May 1.5	31 0	18 33.2	0.356	0.95
5.5	28 46	19 38.4		
9.5	26 18	20 45.7	0.342	1.00
13.5	23 36	21 55.7		
17.5	20 34	23 8.6	0.323	1.00
21.5	17 9	24 25.0		
25.5	13 16	25 45.6	0.299	1.14
29.5	1 8 47	27 10.6		
July 1.5	23 40 41	42 11.3	0.131	1.81
Aug. 1.5	19 33 28	+41 14.4	0.077	1.68

Mt. Hamilton, Cal., 1900 *Mar.* 2.

The unit of brightness is that on February 3.

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POSITION OF THE EQUATOR AND FLATTENING OF *NEPTUNE*, DERIVED FROM THE PERTURBATION OF THE ORBIT OF ITS SATELLITE.

By STIMSON J. BROWN.

An abstract of the following paper was read at the Third Annual Conference of Astronomers at the Yerkes Observatory in September, 1899. I had hoped before publishing the results to include two more recent series of observations of the Lick and Yerkes for 1899.0, but have not been able to do so. Owing to the slow change of the orbit plane, but little improvement could be expected, until the lapse of several years. For the same reason there is but little gain in repeating the observations of the satellite every year. Once in three or four years will in time furnish sufficient material for a more thorough solution of the problem.

Eighteen determinations of the orbit of *Neptune's* satellite have been made from as many series of observations, extending from 1848 to 1898. Owing to the position of the planet and of the plane of the orbit, and the location and small size of the telescopes employed, the results of the earlier series of observations are very discordant. Until the publication of the results of the 26-inch equatorial of the U.S. Naval Observatory,(1) from observations extending from 1873 to 1883, it had not been possible to see with certainty that the orbit plane was slowly changing its position.

MARTH (2) first called attention to the apparently progressive nature of these changes, which were too large to be ascribed to systematic errors of observation, but attempted to assign no cause for the phenomenon. The data presented by MARTH, by a skillful discussion of the problem, enabled TISSERAND to show that the motion could be easily and naturally explained by the assumption of a moderate polar compression of the planet.(3) From the elements of the orbit, for the epochs 1852, 1864, 1874 and 1883, he derived limiting values for the position of the equator of *Neptune* and the corresponding flattening of the planet. His discussion was based upon the assumption of uniform motion of the elements employed, and gave the following results for the flattening of the planet, corresponding to the assumed inclination of the satellite's orbit to the equator of *Neptune*.

Inclination	20°	flattening	$>$ [illegible]
"	25	"	$> \frac{1}{162}$
"	30	"	$> \frac{1}{115}$

The period of revolution of the pole of the satellite's orbit about the polar axis of the planet would exceed 500 years.

HERMAN STRUVE,(1) a few years later, published a memoir on the satellite's orbit, giving with his accustomed thoroughness a discussion of all the material then available. This included four series of observations by himself with the Pulkowa 30-inch refractor, extending from 1887 to 1892, and one by ASAPH HALL, Jr., in 1892–3, with the Washington 26-inch. Although the period was thus extended ten years, he concluded that the motion of the orbit plane was still apparently uniform, and that hence no advance could be made in further defining the limits set by TISSERAND.

In the further discussion of the subject, I have made use of the material presented in STRUVE'S Memoir, in addition to the orbits resulting from Prof. BARNARD'S (2) observations with the Yerkes telescope, and from those made by myself with the 26-inch of the Naval Observatory.(3) I tried first to get more accordant results from the observations of the BONDS, O. STRUVE and LASSELL, but finally ended in accepting the conclusions reached by STRUVE.

The following tabular statement gives the elements of the satellite's orbit, N being the longitude of the node, and

(1) Washington Observations, 1873, 1881, Appendix I.

(2) *Monthly Notices*, Vol. 46, p. 504.

(3) *C. R.*, Vol. 107, p. 804.

(1) *Mém. de l'Acad. Imp. des Sciences de St. Pétersbourg*, 1891, tome 42, No. 4.

(2) *Astr. Jour.*, Vol. 19, pp. 17 and 65.

(3) *Astr. Jour.*, Vol. 20, No. 473.

I the inclination referred to the *Earth's* equator at the epoch of the observations. The column (C – O) I gives the residuals resulting from the following formulas, derived by the method of least-squares, after reducing the observed N's to the equator of 1850, by the formulas $\Delta N = 0°.094\,t$; the change in I due to precession is too small to be taken into account.

$$N = N_0 + \Delta_1 N t + \frac{t^2}{2} \Delta_2 N$$

$$I = I_0 + t.\Delta_1 I + \frac{t^2}{2} \Delta_2 I$$

$$t = (1874.5 - T)$$

$$N_0 = 182°.785 \quad \pm 0.103° \qquad I_0 = 121.736 \quad \pm 0.100$$
$$\Delta_1 N = +0.1444 \quad \pm 0.0047 \qquad \Delta_1 I = -0.1739 \quad \pm 0.0046$$
$$\Delta_2 N = +0.001714 \pm 0.00059 \qquad \Delta_2 I = +0.00147 \pm 0.00058$$

Observer	Mean Epoch	N	$\pm r$	C – O (1)	C – O (2)	C – O (3)	C – O (4)	I	$\pm r$	C – O (1)	C – O (2)	C – O (3)	C – O (4)
Bond	1848.3	178.37	0.86	+0.98	+1.11	+1.34	+1.23	125.05	0.15	(+1.76)	+1.61	+1.49	+1.37
*Bond	1848.3	(180.00)	. .	–0.65	–0.52	–0.29	–0.10	(126.24)	. .	+0.57	+0.42	+0.30	+0.18
O. Struve	1848.6	182.39	1.00	–3.02	–2.87	–2.64	–2.75	126.21	0.18	+0.52	+0.36	+0.21	+0.13
Lassell	1849.8	176.70	0.50	+2.82	+2.94	+3.17	+3.06	126.55	0.21	–0.01	–0.18	–0.30	–0.42
Lassell	1852.9	179.02	0.59	+0.84	+0.97	+1.18	+1.07	126.21	0.39	–0.38	–0.45	–0.55	–0.68
O. Struve	1863.6	181.33	0.77	–0.10	–0.01	+0.14	+0.02	124.22	0.32	–0.52	–0.49	–0.56	–0.67
Lassell	1864.5	181.65	0.42	–0.34	–0.20	–0.15	–0.18	124.19	0.28	–0.64	–0.63	–0.69	–0.81
Newcomb	1874.5	183.03	0.14	–0.21	–0.11	–0.03	–0.16	121.70	0.10	+0.04	+0.09	+0.04	–0.06
Hall	1876.3	183.47	0.33	–0.40	–0.26	–0.20	–0.32	121.64	0.19	–0.21	–0.16	–0.20	–0.30
Holden	1876.5	182.79	0.30	+0.30	+0.45	+0.51	+0.39	121.04	0.18	+0.35	+0.41	+0.37	+0.26
Hall	1882.1	184.05	0.15	–0.05	+0.11	+0.13	0.00	120.03	0.11	+0.43	+0.49	+0.45	+0.33
Hall	1883.8	184.67	0.21	–0.39	–0.21	–0.20	–0.34	120.13	0.23	+0.05	+0.12	+0.09	–0.01
H. Struve	1887.6	184.48	0.15	+0.47	+0.65	+0.63	+0.49	119.38	0.13	+0.21	+0.28	+0.24	+0.16
H. Struve	1889.0	185.05	0.11	+0.14	+0.32	+0.30	+0.16	119.53	0.09	–0.16	–0.09	–0.11	–0.21
H. Struve	1890.6	185.51	0.12	–0.03	+0.16	+0.12	–0.02	119.26	0.10	–0.13	–0.05	–0.07	–0.17
H. Struve	1892.6	185.56	0.18	+0.29	+0.47	+0.41	+0.27	119.06	0.15	–0.23	–0.15	–0.17	–0.27
A. Hall, jr.	1892.0	185.73	0.45	+0.01	+0.19	+0.14	0.00	118.55	0.45	+0.37	+0.44	+0.43	+0.33
Barnard	1898.0	187.22	0.17	–0.35	–0.16	–0.26	–0.40	118.16	0.15	–0.10	–0.02	–0.04	–0.13
Brown, s.j.	1898.0	186.70	0.15	+0.17	+0.36	+0.26	+0.12	117.80	0.14	+0.26	+0.34	+0.32	+0.23
	1905.0	(188.13)						117.10					
	1910.	(189.12)						116.50					

* These values of N and I result from Bond's discussion of his own observations.

The elements for the first five epochs were given a weight of ¼, except Bond's value of I, which it was found necessary to reject, for reasons to be given later. Although these residuals indicate but a slight gain in representing the motion, this is due to the presence of large systematic errors in the early observations, and to a certain extent in the later ones.

In a consideration of the causes producing the motion of the orbit plane, the effect of the *Sun* and the neighboring planets may be neglected, as it amounts to less than 0°.10 per century in N, and still less in I. The existence of an unknown satellite of sufficient size to produce any appreciable effect is very improbable, and it may safely be assumed that the equatorial protuberance of the planet is the sole cause of the phenomenon. Upon this assumption the equator of the planet becomes the invariable plane upon which, in accordance with well known law, the node of the satellite's orbit plane will move with a uniform retrograde motion, while the inclination of the two planes will remain constant.

The analytical expression of this law is

$$\sin\gamma \frac{d\theta}{dt} = c \quad \text{and} \quad \frac{d\gamma}{dt} = 0$$

in which θ is the longitude of the node, and γ the inclination of the satellite's orbit referred to the planet's equator as the invariable plane.

In the spherical triangle formed by the planes of *Earth's* and planet's equators and that of the orbit, these expressions become

$$\sin\gamma \frac{d\theta}{dt} = \cos\psi \sin I \delta N - \sin\psi \delta I \qquad (a)$$

$$\frac{\delta\gamma}{dt} = \sin\psi \sin I \delta N + \cos\psi \delta I \qquad (b)$$

in which ψ is the distance between the orbit's nodes upon the *Earth's* and planet's equators.

From the second of these equations, we have

$$\tan\psi = -\frac{dI}{\sin I \delta N}$$

and ψ is to be taken in that quadrant, which by its substitution in the first equation will make the value of $\sin \gamma d\theta$ negative with respect to the motion of the satellite in its orbit; in this case it is positive owing to the retrograde motion of the satellite.

If the actual motion of the orbit plane is correctly represented by the formulas (a) and (b) derived above, the values of $\sin \gamma d\theta$ for the various epochs will be nearly the same, depending on the accuracy of the elements employed. It was only by the rejection of BOND's value of I, as deduced by STRUVE, that the results could be made at all accordant.

It is interesting in this connection to note that the elements derived by Mr. G. P. BOND([1]) from the same observations, upon the assumption of direct motion of the satellite, when account is taken of the retrograde motion, are in substantial agreement with the theory derived in this paper. The details of work are not given, and I have been unable to reproduce his results. It is also surprising that the mean distance of the satellite which he derives, 16″.30, is very close to the final value derived from a discussion of all the later values derived from observations with the most powerful instruments.

From the values of N, I, ΔN, ΔJ and ψ, for the first and last epochs, there is easily derived the following elements of the equator of *Neptune* referred to the *Earth's* equator, 1850.0:

	1848.3	1898.0	1850
$N - N_0$	157.60	164.66	. .
J_0	18.96	19.12	19.04
γ	17.88	17.96	17.92
$\theta - N_0$	96.47	131.27	97.58
N_0	21.74	21.71	. .

With the assumed elements of the equator of *Neptune* for 1850, thus derived, and $\Delta\theta = 0°.69$, the annual motion of the node of the orbit on the equator of *Neptune*, the values of N and J for the various epochs are easily computed; the comparison of these with the corresponding values derived from observations, gives the residuals (C−O) II. These furnish the basis for the correction of the assumed elements of *Neptune's* equator and the orbit of the satellite by means of the linear equations:

$$\sin J\delta N = \sin\psi\delta\gamma - \cos J \sin(N - N_0)\,\delta J_0 + \cos\psi(\sin\gamma\delta\theta_0) + t\cos\psi\sin\gamma\delta\Delta\theta \left\{-\cos\psi + \frac{\sin J}{\sin\gamma}\right\}(\sin\gamma\delta N_0)$$

$$\delta J = \cos\psi\delta\gamma + \cos(N - N_0)\,\delta J_0 - \sin\psi(\sin\gamma\delta\theta_0) - t\sin\psi\sin\gamma\delta\Delta\theta + \sin\psi(\sin\gamma\delta N_0)$$

Weights were given to equations of condition varying from $\frac{1}{4}$ for the earlier epochs to $1\frac{1}{2}$ for the most of the later. With the exception of the correction to $\Delta\theta$, the results have but little weight owing to the small variation in the coefficient. The residuals in (C−O) III result from the comparison of the values derived from the corrected elements with the corresponding values given in the table. The corrected elements, together with those which will reduce to zero the residuals (C−O) III in both N and I from 1874 to 1898, are as follows:

CORRECTED ELEMENTS.

	III	IV
γ	17.81	17.80
J_0	19.38	19.50
$\Delta\theta$	+0°.6770	+0°.6755
$\theta_0 - N_0$	97.11	97.25
N_0	22.02	21.82

The period of revolution of the node is thus 531 years.

The first set thus represents a close approximation to the two elements of *Neptune's* equator and the position and motion of the orbit plane. At the epoch 1900.0 the position-angle of the polar axis will be 158°.4, and the plane of the equator of *Neptune* will make an angle of −21°.6 to the line of sight.

A confirmation of these conclusions is furnished by the apparent increase in the mean motion of the satellite, when derived from values of u, the angular distance of the satellite referred to the movable node on the *Earth's* equator. The following values have been derived:

Newcomb,	61°.25679	1874.5
Hall,	61.257420S	1883.0
Struve,	61.257428	1890.0

The results of the '98 observations indicate a still larger value. The increase is naturally explained by the progressive increase in ΔN. By referring u to the movable node of the orbit on the planet's equator, the mean motion of the satellite will be affected by a constant amount. This is readily done by subtracting from the value of u for each epoch the corresponding value of ψ. The results of a least-square solution for n, when derived from ($u - \psi$), is shown in the following tabular statement. The values of ψ are taken from the corrected elements (III) of *Neptune's* equator given above.

		u	$u - \psi$		(C−O) II
1848	July 0.0	74.26	4.26	320.20	−1.67)
1852	Nov. 0.0	264.00	196.75	318.32	+0.21
1864	July 0.0	221.59	161.14	319.20	−0.67
1874	July 0.0	13.33	318.52	318.53	0.00
1876	July 0.0	152.11	98.33	317.97	+0.56
1876	July 0.0	152.53	98.86	318.50	+0.03
1882	Jan. 0.0	160.14	109.66	318.60	−0.07
1884	Jan. 0.0	238.55	189.03	318.86	−0.33
1887	Aug. 0.0	82.36	34.99	317.99	+0.54
1889	Jan. 0.0	195.41	148.86	318.43	+0.10
1890	Aug. 0.0	261.06	215.38	318.46	+0.07
1892	Jan. 0.0	312.71	267.82	318.70	−0.17
1892	Aug. 0.0	10.40	355.85	318.54	−0.01
1898	Jan. 0.0	309.10	267.59	318.63	−0.10
1898	Jan. 0.0	309.18	267.67	318.71	−0.18
				318.53	

([1]) *Proc. American Academy*, Vol. 11, p. 136.

$n = 61.2590506$ which corrected for $\Delta\theta \cos\gamma = 0°.00176$ becomes $n = 61.25729$.

This is nearer the true mean daily motion of the satellite, but it differs so little from STRUVE's value that the latter may be safely retained for the present, as the derived mass and flattening of the planet will be but little improved by the change.

The motion of the node of the satellite on the equator of *Neptune* as the invariable plane will be

$$\frac{d\theta}{dt} = -\lambda \frac{k}{a^2} \cos\gamma$$

where λ is the mean annual motion of the satellite.

We have further

$$\frac{K}{r^2} = \left(\chi - \frac{q}{2}\right)$$

r = equatorial radius of the planet.
χ = the flattening.
q = the ratio of centrifugal force to the attraction force of the planet at the equator.

The relation of q to χ is given by CLAIRAUT's equation

$$\chi = \frac{5q}{4 + 6\sigma}$$

where σ varies with the internal constitution of the body from 0, while the planet is homogeneous to +1 when the mass is entirely concentrated at the center. From these equations we get the value of the flattening

$$\chi = \frac{5}{3} \cdot \frac{d\theta}{\lambda \cos\gamma} \cdot \frac{r^2}{a^2(1-\sigma)}$$

The equatorial diameter of the planet is given by STRUVE, from 13 measures with *bright field*, as 2″.238, while BARNARD from about the same number with the Lick 36-inch derives 2″.433, using bright wires. From the fact that STRUVE's values range from 2″.12 with bright yellow field to 2″.27 with dark red, it is evident that even with a faint disk like *Neptune's* the irradiation causes the measured diameter to be too large. The difficulty of placing the center of the micrometer wire on the edge of the planet's disk may, however, easily introduce a systematic error sufficient to explain the difference between those two fine determinations. There is no doubt that the previously accepted diameter, 2″.60, given in standard works in astronomy, is much too great.

The value of a, the mean distance of the satellite, noticed later, is 16.308, from the weighted mean of all the recent work with large telescopes.

Using the various quantities given above, there is easily derived the following table of the value of the flattening corresponding to assumed values of σ and r. There is also added the corresponding period T_0 of rotation of *Neptune*, which is readily deduced from the formula

$$q = \frac{T'^2}{T_0^2} \frac{r^3}{a^3}$$

	$r = 1.10$		$r = 1.20$	
σ	$\frac{1}{\chi}$	T_0	$\frac{1}{\chi}$	T_0
		h		h
0.0	85.1	20.4	101.3	25.3
0.2	68.0	20.0	81.0	24.9
0.3	59.5	17.7	70.9	22.0
0.4	51.0	15.6	60.8	19.4
0.5	42.6	13.6	50.6	16.9
0.6	34.0	11.7	40.5	14.5
0.7	25.5	9.8	30.4	12.1
Saturn		σ	0.776	
Jupiter		σ	0.63	
Earth		σ	0.18	
Mars		σ	0.12	

The mean density of *Neptune* will lie between 1.41 and 1.83, varying with adopted angular value of his radius from 1″.20 to 1″.10.

From a general consideration of the relation of density to the constants χ, q and σ for those planets in which these quantities are known, we may infer a limit between which the value of σ for *Neptune* will probably lie, δ being the mean density.

For *Saturn*,	$\sigma = 0.78$	$\delta = 0.75$
Jupiter,	$\sigma = 0.63$	$\delta = 1.38$
Neptune,	$\sigma = 0.\ ?$	$\delta = 1.83$
Earth,	$\sigma = 0.18$	$\delta = 5.66$
Mars,	$\sigma = 0.12$	$\delta = 4.17$

The low mean density indicates that *Neptune* is still gaseous, like *Jupiter* and *Saturn*, but that the process of condensation, due to radiation of heat, has progressed further. The development in this direction is still far behind the *Earth's*, so that it seems reasonable to infer that the constant σ in the case of *Neptune* is smaller than that of *Jupiter*, say 0.5. The flattening and period of rotation corresponding to this value is given in the table. H. STRUVE in his measurements, found for the diameter in position-angle 235° 2″.183, and at right-angles to this 2.238, corresponding to the minor and major-axis of the satellite's orbit. This gives $\chi = \frac{1}{40}$, in close agreement with the number which I have found for radius 1″.10.

The mean distance and mass of the planet, corresponding to the later observations with large telescopes, is given in the following tabular statement.

Newcomb	16.275	±0.018	M19383	± 64	+935	–
Holden	16.598	±0.035	M18273	±125	–	–465
Hall 75–77	16.482	±0.033	18662	±118		243
Hall 81–82	16.368	±0.022	19054	±079	86	–
Hall 83–84	16.263	±0.028	19425	±100	125	–
Struve 86–93	16.271	±0.012	19396	± 13	2142	–
Hall, Jr.	16.602	±0.072	18260	±257	–	111
Barnard	16.224	±0.028	19565	±100	565	
Brown	16.270	±0.026	19399	± 93	463	–
	16.308	±0.0074	19269	± 26	4615	819
					819	
					3796	

The mean distance and mass derived from the least-square solution of the above results, weighted strictly according to the corresponding probable errors, is

$$a = 16''.308 \pm 0''.0074$$

$$\frac{1}{\mu} = 19.269 \pm 26$$

The value of $\frac{1}{\mu}$ derived from Newcomb's discussion of the perturbative effect of *Neptune* on *Uranus* is

$$\frac{1}{\mu} = 19261$$

The values of N and I for 1905 and 1910 referred to the equator of those dates respectively, are computed from the corrected elements III of the planet's equator, and are added for convenience in the discussion of recent and future observations of the satellite.

I am under obligations to Mr. M. E. Porter, computer, for assistance in the formation and solution of the equations of condition.

U. S. Naval Observatory, Washington, 1900 *January.*

FINDING EPHEMERIS OF *EROS*.

By JAMES B. WESTHAVER.

The following ephemeris of *Eros* is computed with the elements given by Henry Norris Russell in *A.J.* 473.

For Greenwich Mean Midnight.

Date 1900	α h m s	δ ° ′ ″	log Δ	Mag.
April 1	21 58 50.0	−12 11 23	0.37222	13.6
3	22 2 7.3	11 42 26	0.36938	
5	22 7 2.9	11 13 13	0.36646	13.6
7	22 11 7.0	10 43 11	0.36347	
9	22 15 9.5	10 14 2	0.36041	13.6
11	22 19 10.6	9 44 5	0.35728	
13	22 23 10.3	9 13 54	0.35408	13.5
15	22 27 8.8	8 43 29	0.35180	
17	22 31 5.9	8 12 50	0.34745	13.5
19	22 35 1.9	7 41 59	0.34402	
21	22 38 56.6	7 10 55	0.34051	13.5
23	22 42 50.1	6 39 39	0.33693	
25	22 46 42.5	6 8 11	0.33327	13.4
27	22 50 33.6	5 36 31	0.32953	
29	22 54 23.6	5 4 40	0.32571	13.4
May 1	22 58 12.4	4 32 38	0.32182	
3	23 2 0.1	4 0 25	0.31784	13.4
5	23 5 16.7	3 28 2	0.31379	
7	23 9 32.3	2 55 29	0.30966	13.3
9	23 13 16.9	2 22 15	0.30545	
11	23 17 0.5	− 1 49 52	0.30116	13.3
May 13	23 20 43.1	− 1 16 48	0.29679	
15	23 24 24.9	0 43 35	0.29234	13.2
17	23 28 5.8	− 0 10 11	0.28780	
19	23 31 45.8	+ 0 23 22	0.28319	13.2
21	23 35 25.0	0 57 4	0.27849	
23	23 39 3.3	1 30 55	0.27370	13.1
25	23 42 40.8	2 4 55	0.26883	
27	23 46 17.5	2 39 1	0.26387	13.1
29	23 49 53.3	3 13 22	0.25883	
31	23 53 28.1	3 47 48	0.25370	13.0
June 2	23 57 2.6	4 22 22	0.24848	
4	0 0 36.1	4 57 6	0.24317	12.9
6	0 4 8.7	5 31 57	0.23778	
8	0 7 40.7	6 6 57	0.23230	12.9
10	0 11 11.9	6 42 6	0.22674	
12	0 14 42.5	7 17 24	0.22108	12.8
14	0 18 12.4	7 52 51	0.21533	
16	0 21 41.7	8 28 27	0.20949	12.7
18	0 25 10.3	9 4 12	0.20355	
20	0 28 38.1	9 40 5	0.19752	12.7
22	0 32 5.3	10 16 8	0.19140	
24	0 35 31.8	10 52 19	0.18518	12.6
26	0 38 57.5	11 28 39	0.17886	
28	0 42 22.4	12 5 8	0.17244	12.5
30	0 45 46.6	12 41 47	0.16593	
July 2	0 49 10.0	+13 18 34	0.15932	12.5

University of Denver, 1900 *March* 9.

MOTION OF THE PERIHELION OF *MERCURY*.

By A. HALL.

The eclipse of the sun on May 28th will give an opportunity of applying the improved photographic methods to a search for intra-mercurial planets. Although the probability of discovery is small, it is to be hoped the attempt will be made.

The explanation of the motion of the perihelion of *Mercury* from the figure and constitution of the sun seems to me very unsatisfactory. From the expression of the potential, *Méc. Cél.*, Livre III, Art. 35, Laplace finds for the motion of the perihelion of a planet,

$$\delta\pi = (\rho - \tfrac{1}{2} q) \cdot \frac{D^2}{a^2} \cdot nt$$

ρ being the flattening of the sun, q the ratio of the centrifugal force to gravity at the sun's equator, D the semi-diameter of the sun, and a, n, the mean distance, and mean motion of the planet. In this value of $\delta\pi$ the declination of the planet with respect to the solar equator is zero. If we suppose the sun to be a homogeneous body $\rho = \frac{5}{4} q$, and the motion becomes,

$$\delta\pi = \tfrac{3}{4} q \cdot \frac{D^2}{a^2} \cdot nt$$

Reducing this to numbers for the orbit of *Mercury*, we have

$$\delta\pi = +0''.0123\, t$$

the unit of t being a Julian year. The observed motion is forty times greater. If the sun, like *Jupiter* and *Saturn*, be more dense toward the center the above motion will be less. Another force may arise from the solar corona, but from what we know of this appearance its probable effect must be very small.

Again, the time of rotation of the sun on its axis is so great that if we compute the flattening, under the assumption of homogeneity, it is 100 times smaller than that of the earth. This agrees with observations which show no sensible flattening.

1900 *February* 19.

OBSERVATIONS OF COMET 1899 I,

MADE AT THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA,

By C. D. PERRINE.

1899 Mt. Hamilton M.T.	✱	No. Comp.	☄ − ✱ $\Delta\alpha$	☄ − ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Telescope
			m s	′ ″	h m s	° ′ ″			
May 11 15 21 19	1	10 , 6	+1 4.52	−3 11.9	23 23 49.76	+33 49 24.7	n9.727	0.497	36
18 15 13 10	2	10 , 8	−0 13.43	−2 51.0	22 29 34.74	+44 26 4.1	n9.716	9.898	36
19 11 43 15	3	8 , 6	+1 41.84	+2 41.0	22 18 34.68	+46 4 15.6	n9.749	9.934	36
20 15 6 40	4	d10 , 8	−0 10.41	−2 25.0	22 5 52.72	+47 46 12.6	n9.700	n8.602	36
June 6 13 41 47	5	10 , 6	+2 54.72	+3 36.0	16 20 46.39	+48 59 3.2	9.622	n9.908	12
7 13 31 12	6	d10 , 8	+0 2.09	+8 19.8	16 7 56.19	+47 22 9.0	9.625	n9.699	12
8 13 47 50	7	d10 , 8	−0 17.29	−1 31.0	15 56 16.98	+45 42 40.5	9.680	9.301	12
26 13 20 52	8	d10 , 8	−0 6.12	+5 16.6	14 28 58.47	+23 41 14.0	9.702	0.637	12
July 1 12 31 7	9	d10 , 8	−0 34.27	−1 12.5	14 18 25.23	+18 12 18.1	9.681	0.658	12
5 11 54 36	10	10 , 8	−0 43.02	+4 34.8	14 17 35.19	+17 38 34.7	9.661	0.633	12
11 10 53 36	11	10 , 8	−0 33.03	+5 47.4	. . . .	. . . .	9.623	0.631	12
13 11 34 43	12	10 , 8	−0 8.70	+4 18.0	14 13 7.03	+13 42 11.7	9.664	0.671	12
15 10 19 48	13	10 , 8	+1 43.90	−0 21.7	14 12 33.54	+12 53 14.2	9.601	0.635	36
23 9 26 55	14	d10 , 8	−0 13.83	+0 14.8	14 11 14.42	+ 9 59 8.1	9.566	0.651	36
30 8 53 14	16	d10 , 8	−0 10.24	−0 0.1	14 12 31.88	+ 7 52 58.7	9.550	0.667	36
31 8 30 46	18	d10 , 8	+0 12.29	−0 36.0	14 12 43.79	+ 7 36 44.1	9.517	0.665	36

Mean Places for 1899.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 22 43.97	+1.27	+33 52 37.2	−0.6	Leiden A.G. Zone 224, 326
2	22 30 16.60	+1.57	+44 28 59.1	−4.0	Deichmüller, Bonn A.G. 16888
3	22 16 51.20	+1.64	+46 1 39.2	−4.6	" " " 16622
4	22 6 1.44	+1.69	+47 48 42.8	−5.2	" " " 16424
5	16 17 48.38	+3.29	+48 55 31.2	−4.0	" " " 10481
6	16 7 50.82	+3.28	+47 13 53.0	−3.8	" " " 10383
7	15 56 30.99	+3.28	+45 14 15.2	−3.7	" " " 10259
8	14 29 1.53	+3.06	+23 36 2.8	−5.4	Becker, Berlin A.G. 5099
9	14 18 56.52	+2.98	+18 13 36.8	−6.2	Auwers, Berlin A.G. 5203
10	14 18 15.24	+2.97	+17 34 6.2	−6.3	" " " 5199
11	14 14 21.8	+2.93	+14 31.0	−7.0	DM. +14°2723. Mag. 9.3
12	14 13 12.83	+2.90	+13 38 0.8	−7.1	Weisse's Bessel 188
13	14 10 46.78	+2.86	+12 53 43.1	−7.2	" " 136
14	14 11 55.42	+2.83	+ 9 59 1.0	−7.7	11M. Connected with ✱15
15	14 10 10.11	+2.82	+ 9 54 43.3	−7.8	Weisse's Bessel 126
16	14 12 39.37	+2.75	+ 7 53 7.0	−7.9	12M. Connected with ✱17
17	14 14 7.83	+2.76	+ 7 50 43.6	−7.8	Leipzig II, A.G. 6663
18	14 12 28.76	+2.74	+ 7 37 28.0	−7.9	13M. Connected with ✱19
19	14 8 53.15	+2.72	+ 7 35 43.0	−8.1	Leipzig II, A.G. 6643

NOTES.

In No. 464 of this Journal I have published measures of the second nucleus which developed in this comet previous to May 11. The following measures complete the series on the secondary nuclei of this comet:

Greenwich M.T.	°	″	Magnitudes	
1899 May 18.96	246.4	25.2	9.0	11.0
19.97	243.4	26.5	9.5	11.0
20.98	241.0	29.4	9.5	11.5

The comet was again examined on May 26, but under poor conditions, there being a nearly full moon, and rather poor seeing. Following are my observing notes: "Whole comet is very much fainter. Nucleus is sharp, and 10^M or $10\frac{1}{2}^M$. Cannot be certain of the second nucleus."

The comet was next observed on June 3d, when the nucleus was of the $9^M.0$, and very sharp. The second nucleus was not seen, but a slight brightening in the head about 1′ south of the nucleus was suspected.

On June 4th, the nucleus was stellar and of $8^M.5$. Surrounding the nucleus was a bright condensation, similar to that of May 6th, which was elongated south. This feature was better seen with a power of 520. With the higher power, the principal nucleus resembled a disc 1″ in diameter. A set of measures at $21^h\ 57^m$ Greenwich M.T., gave 178°.0 and 23″.4.

On June 6th, 7th, and 8th, this appendage was measured with the 12-inch equatorial, using a power of 150, with the following results:

	°	″	M	M
June 6.93	170.8	12.4	10 and	12
7.91	163.1	12.1	10½	13
8.92	155.6	16.2	10½	13

On June 8th, the secondary condensation was very faint, and in consequence the settings are somewhat uncertain. The following measure was made with the 36-inch refractor:

June 9.89	149°.0	16″.9

On this date it was noted as "an extension of (brighter) nebulosity from the nucleus rather than a separate condensation."

On June 26th, the comet had become faint, not being brighter than 10^M. The nucleus was estimated at 12^M–13^M.

May 12th, Brightest nucleus estimated as 4″ diameter; seeing poor. — 18th Comet 4^M. — 20th, Head of comet much fainter. — *June* 4th, Comet fully 5^M. — 6th, Comet fully 5^M. — 8th, Comet fully 5^M. — 26th, Comet 2′ in diameter. — *July* 4th, Comet 11^M; diameter 1′; very faint nucleus. — 5th, Nucleus very faint; 15^M. — 11th, Comet 1′ or 1½′ in diameter; $10\frac{1}{2}^M$ or 11^M; faint nucleus. — 13th, Comet 11½ or 12^M. — 14th, Comet not brighter than 12^M. — 21st Comet 12^M–13^M; 10″–15″ diameter; condensation (36). — 30th, Comet 13^M or fainter; very faint nucleus. — 31st, Comet $12\frac{1}{2}^M$; nucleus 15^M.

July 11th, the observed distance between the comparison star and DM. +14 2718, mag. 6.8, on Dec. 25 was (2723–2718), $\Delta\alpha$ +4 $39^s.33$, $\Delta\delta$ +4′ 5″.9, corrected for refraction.

In observations marked *d*, $\Delta\alpha$ was measured directly with the micrometer.

Mt. Hamilton, Cal., 1900 *March* 5.

NOTE ON A NEW METHOD OF DETERMINING THE SOLAR APEX.

By EVERETT I. YOWELL.

In *A.N.* 3591–92, Dr. Kobold finds the position of the solar apex, by a modification of Bessel's method, to be $\sigma = 269°\ 40'.8$, $\tau = -0°\ 1'.4$. As this method offered a new way of treating the data at hand, I made the following preliminary investigation at Dr. Porter's suggestion. The proper motion stars used were 86 fundamental stars of the *Berlin Jahrbuch* for which $0''.2 < \mu_s < 0''.5$. These stars had already been used to determine the apex by Airy's method, and the resultant position found was $\sigma = 284°.14$, $\tau = 34°.11$. Two computations were made according to Kobold's method, using in each case equation (5 *a*), but omitting the term in dp. In the first computation, the approximate position of the apex was assumed to be $\sigma = 270°$, $\tau = 0°$ and the corrections found were $d\sigma = +0°.03$, $d\tau = +0°.01$; in the second computation, the assumed approximate position of the apex was $\sigma = 281°$, $\tau = +34°$ and the corrections found were $d\sigma = -0°.07$, $d\tau = -0°.12$. It would seem from these results that Kobold's method would give small corrections to any assumed position of the apex, thus leaving its true position indeterminate.

Cincinnati Observatory, 1900 *March* 2.

OBSERVATIONS OF HOLMES'S PERIODIC COMET 1899 II.

MADE AT THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA WITH THE 36-INCH EQUATORIAL.

By C. D. PERRINE.

Mt. Hamilton M.T.	✳	No. Comp.	☄ − ✳ $\Delta\alpha$	☄ − ✳ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
1899			m s	′ ″	h m s	° ′ ″		
June 15 14 35 8	1	d10 , 8	+0 3.63	−1 27.0	1 23 47.61	+18 59 55.1	n9.686	0.658
16 11 56 3	3	d10 , 8	+0 0.65	−3 35.8	1 25 27.81	+19 18 13.8	n9.675	0.760
17 15 1 13	5	d10 , 8	−0 15.12	−1 0.2	1 27 6.85	+19 36 21.6	n9.669	0.622
July 6 14 51 36	6	10 , 6	−3 15.62	−1 15.3	1 57 22.45	+25 12 15.8	n9.655	0.525
7 14 15 1	7	d10 , 8	+0 11.46	+2 51.4	1 58 51.69	+25 29 9.1	n9.689	0.577
9 14 53 59	8	d10 , 8	−0 3.91	+3 24.8	2 1 56.67	+26 1 10.5	n9.650	0.504
14 15 8 59	10	d10 , 8	+0 1.59	+1 23.6	2 9 24.96	+27 30 3.9	n9.620	0.438
15 15 10 48	12	d 8 , 6	−0 2.42	+0 17.2	2 10 52.97	+27 47 6.0	n9.615	0.425
Sept. 30 12 8 29	14	d10 , 8	+0 5.20	+1 28.2	3 7 7.62	+46 35 1.1	n9.592	n9.716
Oct. 28 12 59 1	16	d10 , 8	+0 25.53	+0 12.5	2 11 11.05	+49 15 3.3	9.155	0.243
Nov. 6 15 44 43	18	4	. . .	+2 35.3	. . . . .	+49 1 11.7	. .	0.079
6 15 51 49	18	d 6	+0 5.16	. . .	2 30 32.97	. . .	9.818	. .
Dec. 24 10 0 49	19	d10 , 8	+0 17.46	+3 21.1	2 5 46.51	+43 10 27.0	9.537	n9.255
1900 Jan. 20 10 2 50	21	d 8 , 6	+0 10.81	−1 41.0	2 23 15.27	+40 13 53.9	9.702	0.167

Mean Places for 1899.0 and 1900.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 23 12.00	+1.96	+19 1 11.0	+ 8.1	10M.5. Connected with *2
2	1 27 42.76	+1.95	+18 58 27.9	+ 8.0	Auwers, A.G. Berlin 149
3	1 25 25.18	+1.98	+19 21 11.6	+ 8.0	12M. Connected with *4
4	1 27 21.78	+1.97	+19 22 7.6	+ 8.0	Auwers, A.G. Berlin 144
5	1 27 19.97	+2.00	+19 40 13.8	+ 8.0	Auwers, A.G. Berlin 142
6	2 1 5.52	+2.55	+25 13 22.8	+ 8.3	½ (Graham, Camb. E., A.G. 1138+Becker, Berlin A.G. 633)
7	1 58 37.63	+2.60	+25 26 6.2	+ 8.5	Graham, Camb. E., A.G. 1122
8	2 1 57.92	+2.66	+26 0 37.1	+ 8.6	13M. Connected with *9
9	2 4 5.35	+2.65	+26 0 22.8	+ 8.5	Graham, Camb. E., A.G. 1155
10	2 9 20.58	+2.79	+27 28 31.8	+ 8.5	10M. Connected with *11
11	2 8 42.74	+2.79	+27 28 33.6	+ 8.5	Graham, Camb. E., A.G. 1191
12	2 10 52.57	+2.82	+27 46 10.4	+ 8.4	13M. Connected with *13
13	2 13 25.43	+2.81	+27 45 2.5	+ 8.4	Graham, Camb. E., A.G. 1233
14	3 6 56.53	+5.89	+46 30 21.1	+11.8	13M. Connected with *15
15	3 6 43.82	+5.89	+46 26 1.9	+11.8	Deichmüller, Bonn, A.G. 2693
16	2 41 8.84	+6.68	+49 14 0.1	+20.7	12M. Connected with *17
17	2 39 28.44	+6.68	+49 13 37.8	+20.9	Deichmüller, Bonn, A.G. 2349
18	2 30 21.09	+6.72	+49 1 42.4	+24.0	Deichmüller, Bonn, A.G. 2199
19	2 5 23.13	+5.92	+43 6 32.4	+33.5	10M. Connected with *20.
20	2 3 11.42	+5.89	+43 5 23.9	+33.7	Deichmüller, Bonn, A.G. 1832
21	2 23 32.60	+1.86	+40 15 19.7	+15.2	11M. Connected with *22
22	2 24 26.53	+1.87	+40 15 22.6	+15.2	Deichmüller, Bonn, A.G. 2116

NOTES.

In observations marked *d*, $\Delta\alpha$ was measured directly with the micrometer.

June 15th, Comet not appreciably brighter than on June 10. — 16th, Comet very faint. — 17th, No change in brightness. — *July* 6th, Comet slightly brighter than last observation, 15M. — 9th, Comet brighter than on July 7th, 14M; has a faint nucleus. — 14th, Sky thick with haze. — 15th, Comet 20″-30″ in diameter, 15½M; brighter at center; sky smoky. — *Sept.* 30th, Comet 14½M, 15″ diameter; brighter at center but no nucleus. — *Oct.* 28th, Comet 14M, 20″ diameter; central condensation but no nucleus. — *Nov.* 6th, Comet 15M. — *Dec.* 24th, Comet faint, 16M; diameter 10″-15″. Comet near a 14M star. — *Jan.* 20, Comet very faint, 16M; several faint stars near.

Mt. Hamilton, California, 1900 *March* 10.

NOTE ON THE SMALL STARS NEAR *SIRIUS*,

By E. E. BARNARD.

The object mentioned in my paper on this subject in *A.J.* 477, as occupying the following position.

Position-angle 281° , Distance 40″.25

and there designated as *H*, is not a real object. It is a reflection from *Sirius*.

There are two of these objects exactly diametrically opposite each other, and at the same distance, so that reversing the telescope will simply substitute one for the other.

Yerkes Observatory, 1899.

A similar object is seen near *Procyon*. The following measures were made on the morning of November 26:

For *Sirius*.

Pos. Angle	Distance	
279°.2	38″.37	Observer west of pier

For *Procyon*.

278°.1	39″.95	Observer east of pier

The objects are therefore reflections from the object-glass. They did not exist prior to 1899 August 29, on which date the object-glass was taken from its cell and cleaned.

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FEASIBILITY OF DETERMINING THE SOLAR PARALLAX BY OBSERVATIONS OF *EROS*, AT THE COMING OPPOSITION, 1900-01.

By SIMON NEWCOMB.

It would seem that at the coming opposition of *Eros*, a better opportunity for determining the parallax of the *Sun* by direct measurement will be offered than was ever before enjoyed.

So far as can be foreseen another such opportunity will not be presented for more than thirty years. The object of the following study is to fix upon the best combination of observations.

Very remarkable is the period through which observations may be extended. During the five months from the middle of October to the middle of March the distance of the planet will be less than 0.50.

The high degree of precision which recent investigations show to be attainable by photography suggests this as the best method. An additional consideration in favor of the photographic method is that photographic telescopes well adapted for the purpose are actually in use at various favorably situated stations, and need only to be applied to this special problem in order to afford a solution.

The conditions of the problem admit of being presented graphically by projections of the terrestrial sphere from time to time during the opposition, based on the following considerations: The parallactic displacement of the planet, as seen from any two points on the earth's surface, is the angular distance between those points as seen from the planet. If, therefore, we project the earth on a plane perpendicular to the line from us to the planet we can determine by inspection both the amount and direction of the displacement between any two stations. I present four such projections with this paper. In their preparation I have been efficiently aided by Dr. C. R. CRUM, student at the Johns Hopkins University. It may be remarked that they make no pretence to precision, being intended only to enable one to see the relative importance of observations at various stations and at various hours of the night by simple inspection and rude measurements.

Making abstraction of all professional details in applying the photographic process,—details which I must leave to practical experts,—there are three objects to be kept in view in arranging the observations.

First, the station and hours of exposure should be so chosen as to secure the maximum of parallactic displacement.

Secondly, we should aim at having nearly simultaneous exposures made at different stations, in order to lessen the uncertainties arising from differences of scale on the two plates, changes in the relative position on the planet among the stars, and the necessity of reduction of the position of the planet from one hour to another. The necessary uncertainty of the positions of the stars of reference, as well as of the computed motion of the planet will be such that we must secure series of independent determinations, each made within an interval of 24 hours.

Thirdly, the relative displacement should, as nearly as possible, be in a direction at right-angles to the motion of the planet among the stars. The image of the planet will in consequence of this motion appear on the plates as a short trail. This form will not diminish the accuracy of the measures in a direction at right-angles to its length, but may diminish it in the direction of its length.

On the projections which follow, the parallels of diurnal motion described by stations at different latitudes on the earth's surface are shown. That of 60° may be taken as corresponding to Helsingfors and Pulkowa; 50° to Greenwich, Paris, Potsdam and other stations in Central Europe; 40° to the American and Southern European stations; 15° to Jamaica and Madras should stations be occupied at these points; −15° to Arequipa, and −35° to the Cape of Good Hope.

The projections have been made approximately for the following times or periods:

I. From the middle of October to the latter part of November

II. About December 16.

III. About January 10.

IV. About February 1

The dotted arc on each projection shows the sunset line, which on the first projection is continuous with the line of sunrise. Within the region marked "day" observations are of course impossible, while the region marked "night" should be supplied with a border about 12° broad, indicating the region of twilight within which photographs cannot practically be taken. This border I have not supplied; its breadth will be one centimetre or less, according to the position.

The arrows indicate the direction of motion of the planet at different dates; the approximate angle which they make with the direction of displacement may be seen by inspection.

As a further aid, I give the following table, showing the principal particulars to be taken into consideration. They are given for the beginning and middle of each month, and make no pretension to numerical exactness. I may remark, in this connection, that Mrs. E. B. Davis prepared for me a complete ephemeris of the planet from October 1 to February 18, from Russell's elements in *A.J.*, No. 473. Just as this ephemeris was completed there appeared one by Millosevich in the *Astronomische Nachrichten*, which is probably more accurate. I do not therefore consider it necessary to publish Mrs. Davis's ephemeris.

Opposition of *Eros*, 1900–01.

Date	App. time of Transit	Decl.	G.C. Motion in One Minute R.A.	G.C. Motion in One Minute Decl.	Dist. from Earth	Hor. Par.
	h m	°	″	″		″
1900 Oct. 1	14 13	+45	+0.05	+0.92	0.574	15.3
16	13 14	50	−0.33	+0.78	0.481	18.3
Nov. 1	11 50	54	−0.70	+0.33	0.414	21.2
16	10 20	54	−0.67	−0.29	0.360	24.4
Dec. 1	8 58	50	−0.19	−0.91	0.331	26.6
16	7 58	45	+0.51	−1.02	0.318	27.7
1901 Jan. 1	7 16	38	+1.23	−1.08	0.316	27.8
16	6 53	32	+1.68	−1.06	0.324	27.1
Feb. 1	6 43	25	+2.08	−1.01	0.344	25.6
16	6 39	19	+2.20	−0.94	0.374	23.5
Mar. 1	6 35	15	+2.17	−0.86	0.410	21.5

We now proceed to a study of the projections in detail.

Projection I.

During the first five days of October the conditions will be most favorable for morning and evening observations at Jamaica and Madras. The maximum of parallactic displacement for morning and evening exposures will be 27″. If both stations are utilized, simultaneous observation made at Madras in the morning, and at Jamaica in the evening, will be available, the displacement being the same. About October 3 the motion of the planet will be at right-angles to the line of displacement, which would be substantially the same whether observations at one station or both are compared.

Through the remainder of the month of October and up to near the middle of November, these conditions will become more and more favorable as regards the amount of parallactic displacement, but will speedily become unfavorable as regards the line of motion of the planet. About November 9 the latter will be parallel to the line of displacement. About the same date the evening exposures will be belated, and the displacement consequently diminished, by twilight, while the parallax is still increasing. The maximum of 40″ is reached about the middle of November.

During the first half of October simultaneous exposures at Helsingfors and Arequipa would be practicable; those at Helsingfors being taken about 16 hours App. T; those at Arequipa about 11 hours. About October 20 the direction of motion will be at right-angles to the line of displacement between these two stations. The maximum of the latter will during this period range from 25″ to 30″.

Projection II.

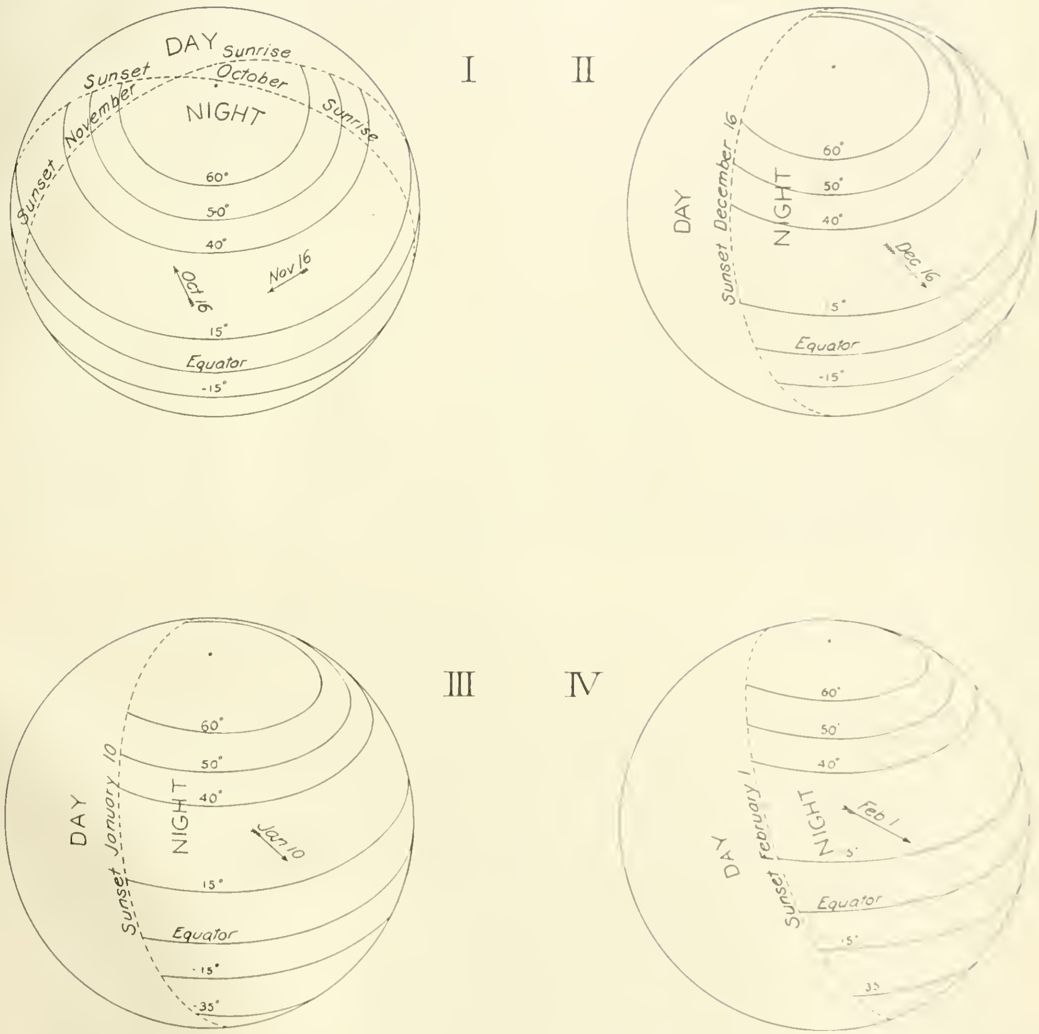
It will be seen that, by the middle of December, the available arc at Jamaica will be materially curtailed through the planet being near the meridian when it can first be photographed; still a displacement of 32″ is practicable, and will be once more in a direction nearly at right-angles to the motion. Absolutely simultaneous observations at Jamaica and Madras will not be practicable owing to the planet being too near the western horizon of Madras at the moment when it can first be photographed at Jamaica.

Most favorable during this period will be simultaneous observations at Helsingfors and Arequipa, the latter being taken on the meridian between 7^h and $7^h\ 30^m$ App. T, the former about 14 hours. By waiting 2 or 3 hours longer at Helsingfors the displacement will be increased to 48″ at the expense of a reduction for motion. The line of displacement will be at right-angles to that of motion during the first half of December, but will become more oblique during the latter half. Fully as great will be the displacement between Arequipa at one end and Potsdam, Greenwich and Paris at the other; but a reduction for motion will be necessary.

Projection III.

Between January 1 and 10 it may be expected that the planet will, for the first time, admit of being advantageously photographed at the Cape, the exposures being made about one hour after meridian transit. The maximum displacement for simultaneous observations at Helsingfors will be about 10″; the direction about 45° with that of motion. Plates taken later in the night at Helsing-

EROS, OPPOSITION OF 1900-01.



fors will give a displacement approaching the practical maximum of 48″, but involving a reduction of 5″ or 6″ on account of motion.

PROJECTION IV.

This projection, made for the beginning of February, will answer through that month, and into March. Nearly simultaneous observations at the Cape and Helsingfors may be combined with a maximum displacement ranging from 40″ about February 1 to 34″ at the end of the month: for simultaneous observations, the obliquity of direction will be some 30°, and will diminish in the course of the month. The obliquity will be still farther diminished and the displacement increased by including in the combination exposures made at Helsingfors at an hour angle of 5 hours, which will involve a reduction of about 8′ for motion. The displacement will then range from 40″ at the beginning of the month to 34″ at the end.

In what precedes, I have dwelt principally upon Helsingfors and the two southern stations already supplied with photographic telescopes. But exposures on approximately similar lines may be combined for at least two stations where, perhaps, the smallness of the displacement will be compensated by the superior quality of the instruments. These are Potsdam and Jamaica. At the most favorable times during November and December nearly or quite simultaneous observations may be taken at Arequipa, Jamaica, Greenwich, Paris, Potsdam and Helsingfors, the combination of which will greatly strengthen the result. Between Potsdam and Jamaica alone the displacement will be about 30″.

Another question to be considered is what degree of precision we may expect in the final result, should such a plan as that suggested be carried out. An extremely favorable circumstance is that the course of the planet during the entire period will lie along the borders of the Milky Way, insuring more and nearer comparison-stars than we should otherwise have. As to the degree of precision attainable in the comparison the data are not at all accordant. For KAPTEYN's investigation of the plates taken for parallax at Helsingsfors, where images of stars taken on the same plate at intervals of six months were compared, it would seem that the probable error of the measurements would be only 2 or 3 hundredths of a second. These measures implicitly involve comparisons of stars widely apart on the same plate, so that there seems to be no evident reason why a degree of accuracy should not be attainable in the present case when two plates taken simultaneously at different stations are compared. On the other hand the Potsdam measures for the photographic indicate probable errors ranging from 0″.06 to 0″.16, according to circumstances, and adopted methods. Let us assume that, by repeated measures, on the same plate, the probable error would be as great as 0″.10. Then the probable error of the solar parallax from a pair of simultaneous plates at Arequipa and Helsingfors would be ±0″.02. If the attainable degree of precision corresponded to that reached in the case of the parallax it would be reduced below 0″.01. I should feel hopeful of reaching the latter degree were it not for the uncertainty arising from the motion of the planet. In any case it seems very clear that a campaign of the kind here proposed is well worth entering upon.

THE HARVARD OBSERVATIONS OF THE SATELLITE OF *NEPTUNE* IN 1847 AND 1848.

By A. HALL.

The satellite of *Neptune* was discovered by LASSELL Oct. 10, 1846, and the next year observations for the determination of the orbit of the satellite and the mass of the planet were begun by LASSELL at Liverpool, by O. STRUVE at Pulkowa, and by the BONDS at the Harvard Observatory. The observations at Harvard were continued through the opposition of 1848. At Pulkowa and at Harvard, filar micrometers were used with the 15-inch refractors. LASSELL also appears to have used a filar micrometer with his 20-foot reflector, but without a driving clock.

One of the earliest orbits of the satellite was computed by Professor BENJAMIN PEIRCE, apparently from the observations of 1847. PEIRCE found the mean distance of the satellite 16″.5, and hence the mass of *Neptune* $\frac{1}{18780}$. He says the limits of the mass are $\frac{1}{19500}$, and $\frac{1}{17000}$. This has proved to be a true statement. After the observations of 1848 G. P. BOND corrected PEIRCE's orbit and found the mean distance 16″.3, and the mass of the planet $\frac{1}{19400}$, which is probably very near the correct value. But the fortune of these results, so nearly right, was singular, since they were completely set aside and ignored for a long time. A discussion of the Pulkowa observations gave the mean distance 17″.95, and the mass $\frac{1}{14400}$. This erroneous value was deduced with all the formality of the method of least-squares, and it was adopted by astronomers for thirty years, or until the observations at Washington with the 26-inch equatorial showed beyond doubt that this value is wrong. One might imagine that astronomers would have been a little more thoughtful, and would have considered the evident fact that the Harvard observers had a decided advantage in geographical position. Since the planet was in twelve degrees south declination the Pulkowa observer had

to do his work at a zenith distance of at least seventy degrees. At Harvard this distance was so much less that such a faint object as this satellite would be more easily observed.

Knowing that the BONDS were conscientious observers, who gave much care to their work, I thought it might be well to revise the reductions of the Harvard observations, and compute an orbit from the observations of 1847 and 1848. Unfortunately the observing books of 1848 can not be found. I only made a change in the time of Oct. 27, and a small correction in the distance of Nov. 2. In all else the observations stand as they are printed. To show the quality of these observations I have carried back the orbit computed from BARNARD's observations (*A.J.*, No. 441) to 1848.0, and find the elements as follows:

$$\begin{aligned} \text{Epoch} &= 1848.0 \text{ Greenwich M.T.} \\ u &= 84^\circ.50 \\ J &= 126.1 \\ N &= 179.0 \\ n &= 61.25742 \\ a &= 16''.30 \end{aligned}$$

Gr. M.T.		h	m	p_c (°)	p_o (°)	s_c (″)	s_o (″)	Obs.
1847 Oct.	25	8	24.3	229.56	230.0	15.19	15.4	B
	27	8	9.0	33.59	28.8	13.95	13.5	B
	27	8	39.0	34.04	28.2	14.14	13.8	B_1
	28	7	53.8	50.31	47.5	14.88	14.7	B
	28	8	53.8	51.12	46.0	14.56	15.2	B_1
	30	7	53.3	214.44	217.9	14.28	15.6	B_1
Nov.	2	7	53.3	35.85	34.2	14.83	14.3	B_1
	3	7	38.1	52.58	51.4	13.93	12.6	B
	26	7	39.9	43.76	49.9	16.26	15.3	B
	26	8	21.9	44.50	40.1	16.23	16.6	B_1
1848 July	3	16	28.1	221.97	221.0	16.60	16.2	B_1
	3	17	21.1	222.95	217.2	16.52	16.2	B
	11	15	56.9	29.03	24.3	12.06	12.0	B_1
	21	15	43.1	227.39	234.0	15.13	16.2	B_1
Aug.	31	11	1.0	222.82	225.0	16.83	17.1	B_1
	31	11	30.0	223.10	. .	16.80	16.1	B
Oct.	11	8	31.3	219.60	219.8	16.44	16.4	B_1
	12	10	51.2	241.39	245.0	9.73	9.6	B
	20	10	34.2	43.48	41.3	16.56	15.7	B_1
	20	10	50.2	43.64	. .	16.53	15.8	B
	23	8	14.8	222.98	219.5	16.58	15.6	B
	23	8	44.8	223.28	223.0	16.55	17.0	B_1
	28	8	39.2	207.16	211.8	11.25	11.2	B_1
Nov.	1	7	38.7	45.33	41.5	16.11	16.5	B_1

Cambridge, 1900 *March* 15.

The preceding table gives the angles and distances of the satellite computed from the above elements, which are nearly correct, and also the observed values. The first column gives the mean time corrected for aberration. The observers are denoted by B for W. C. BOND, and by B_1 for G. P. BOND.

The observations evidently contain large accidental errors, such as we might expect from the faintness of the satellite, but appear free from systematic errors. It is not surprising therefore that PEIRCE and BOND found nearly the right value of the mass of the planet. In order to follow the method, which my acquaintance with G. P. BOND makes me think was chosen by him to correct the orbit, I reduced all the complete observations of 1848 to the mean distance of the planet, and Professor ROBERT WILLSON kindly made a plot of the angles and distances on a large scale. The maximum distances at the elongations are 16″.50, and 16″.27. Drawing the curve through the positions at elongations we have at once BOND's value, 16″.3. Since the apparent orbit was a very eccentric ellipse, the position in the plane of the orbit could not be well determined. The satellite was too faint to be observed at conjunction, and the value of the minor axis remains uncertain. The node and inclination will also be uncertain. I take from Professor WILLSON's plot the values,

$$a = 16''.3 \qquad b = 4''.3 \qquad p = 45^\circ.0$$

for the semi-axes, and the angle of position of the major-axis. Combining these values with the position of the planet we have,

$$J = 127^\circ.87 \qquad N = 183^\circ.31$$

Probably we can now compute these quantities with greater accuracy than they can be found from the early observations.

This examination has convinced me that the Harvard observations of this satellite in 1847 and 1848 are the best that were made in those years. It is not necessary to say much of the difficulties found in discussing the Pulkowa observations: — the assumption that the satellite had changed its mean distance, the rejection of the observed distances, and the application of a large and uncertain systematic correction to the angles. All this may serve as a warning. The conclusion is that the simple and careful work of the BONDS gave the true result.

OBSERVATIONS OF ONE HUNDRED NEW DOUBLE STARS,

BY WILLIAM J. HUSSEY.

I have found the stars of the following list to be double, and have not succeeded in identifying them with any previously known. To avoid cataloguing as new stars already known to be double, I have consulted the lists of the HERSCHELS, the STRUVES, the CLARKS, BURNHAM, DAWES, DEMBOWSKI, HOUGH, INNES, SECCHI, SEE, and

several others, including those of the observers of the Cincinnati, Harvard, McCormick and Washburn Observatories.

Some of the stars of the present list have been discovered with the 12-inch telescope, others with the 36-inch. Nearly all the measures have been made with the latter instrument. In making the measures a power of 1000 has generally been used. Higher powers have been employed on some of the closer pairs, and a lower one for some of the wider ones. In general each position-angle has been derived from the mean of four settings of the circle, and each distance from three double distances.

I have generally rejected pairs where the distance between the components exceeds 5″. Number 30 is an exception; the magnitude of the principal star seems to justify its retention, although the distance is 5″.30. Some of the stars of this list might have been regarded as triple if distances slightly greater than 5″ had been admitted.

Two-thirds of these stars have distances under 2″; 40 are under 1″, and 15 are half a second or less.

The positions of the stars are for the epoch 1900. My estimates of the magnitudes are given in the last columns.

1. DM. −12°6613.

$\alpha = 0^h\ 1^m\ 38^s$; $\delta = -12°\ 43'.2$

	°	″	M	M
1899.648	104.8	1.10	9.2	10.5
.722	104.4	1.04	9.2	10.0
.821	102.7	1.06	9.0	9.5
1899.73	104.0	1.07	9.1	10.0

2. DM. −12°2.

$\alpha = 0^h\ 3^m\ 12^s$; $\delta = -11°\ 57'.1$

1899.648	68.0	3.72	9.1	11.0
.722	69.2	3.77	9.0	10.0
.821	67.7	3.70	9.1	10.0
1899.73	68.3	3.73	9.1	10.3

3. DM. −11°36.

$\alpha = 0^h\ 11^m\ 53^s$; $\delta = -10°\ 53'.8$

1899.648	108.0	1.60	9.1	9.1
.722	108.9	1.58	9.1	9.1
.821	104.7	1.48	9.0	9.5
1899.73	105.9	1.55	9.1	9.2

4. DM. −13°61.

$\alpha = 0^h\ 19^m\ 7^s$; $\delta = -13°\ 37'.9$

1899.722	52.7	0.63	9.0	9.0
.898	55.2	. .	. .	. .
.993	56.9	0.64	9.0	9.0
1899.87	54.9	0.64	9.0	9.0

5. DM. −13°109.

$\alpha = 0^h\ 34^m\ 3^s$; $\delta = -13°\ 5'.3$

1899.585	133.0	1.12	9.0	9.0

6. DM. −10°291.

$\alpha = 1^h\ 16^m\ 57^s$; $\delta = -9°\ 59'.2$

1899.756	239.0	0.59	9.2	9.2
.917	240.8	0.60	9.2	9.2
.933	241.2	0.61	9.0	9.5
1899.87	240.3	0.61	9.1	9.3

This is the companion of *h* 2039.

7. DM. −10°312.

$\alpha = 1^h\ 23^m\ 10^s$; $\delta = -9°\ 47'.7$

1899.917	211.0	1.56	9.0	10.0
.993	212.5	1.67	9.0	10.0
1900.070	212.6	1.66	9.0	9.5
1899.99	212.0	1.63	9.0	9.8

8. DM. −11°313.

$\alpha = 1^h\ 33^m\ 41^s$; $\delta = -11°\ 12'.2$

	°	″	M	M
1899.917	30.3	1.22	8.5	12.0
.933	27.4	1.32	8.5	12.0
1899.92	28.9	1.27	8.5	12.0

9. DM. −12°313.

$\alpha = 1^h\ 36^m\ 24^s$; $\delta = -12°\ 39'.1$

1899.881	293.9	4.56	9.0	9.2
.917	293.3	4.70	9.0	9.0
.933	293.1	4.61	9.0	9.2
1899.91	293.1	4.62	9.0	9.1

10. DM. −13°312.

$\alpha = 1^h\ 37^m\ 36^s$; $\delta = -12°\ 49'.6$

1899.881	304.5	0.78	8.5	9.0
.917	303.5	0.72	8.5	9.0
.933	305.1	0.77	8.5	9.0
1899.91	304.4	0.76	8.5	9.0

11. DM. −12°324.

$\alpha = 1^h\ 39^m\ 44^s$; $\delta = -12°\ 9'.7$

1899.756	203.1	3.02	8.5	11.5
.933	204.2	3.18	8.5	13.0
1900.070	202.6	. .	. .	. .
1899.92	203.4	3.10	8.5	12.2

12. DM. −10°390.

$\alpha = 1^h\ 46^m\ 50^s$; $\delta = -10°\ 25'.2$

1899.756	351.6	1.00	9.1	11.0
.933	355.2	1.02	9.0	11.5
1899.84	353.4	1.01	9.0	11.2

13. DM. −12°364.

$\alpha = 1^h\ 53^m\ 2^s$; $\delta = -12°\ 26'.8$

1899.881	104.6	0.95	8.5	9.0
.933	102.8	1.05	8.5	9.0
1899.91	103.7	1.00	8.5	9.0

14. DM. −11°397.

$\alpha = 1^h\ 59^m\ 15^s$; $\delta = -11°\ 29'.7$

1899.881	19.4	3.54	9.1	9.1
.933	18.2	3.77	. .	. .
1899.91	18.8	3.66	9.1	9.1

15. DM. −11°400.

$\alpha = 2^h\ 0^m\ 8^s$; $\delta = -11°\ 19'.7$

	°	″	M	M
1899.881	8.0	1.57	8.5	10.0

16. DM. −10°438.

$\alpha = 2^h\ 3^m\ 46^s$; $\delta = -10°\ 35'.7$

1899.722	330.2	1.18	8.8	9.3
.917	329.6	1.03	9.0	11.0
1900.034	327.4	0.99	9.0	10.0
1899.89	329.1	1.07	8.9	10.1

17. DM. −13°396.

$\alpha = 2^h\ 5^m\ 35^s$; $\delta = -13°\ 36'.0$

1899.722	261.3	1.95	9.1	10.0
.917	259.4	2.12	9.0	11.5
1900.034	259.7	1.96	9.1	11.5
1899.89	260.1	2.01	9.1	11.0

18. DM. −11°467.

$\alpha = 2^h\ 23^m\ 44^s$; $\delta = -11°\ 4'.6$

1900.034	249.6	4.26	8.5	13.0
.128	250.8	4.67	8.5	12.0
.131	250.9	4.50	. .	. .
1900.10	250.4	4.48	8.5	12.5

19. DM. −11°632.

$\alpha = 3^h\ 13^m\ 12^s$; $\delta = -1[illegible]°\ 56'.1$

1899.756	300.1	3.27	8.5	10.2
1900.034	301.0	3.23	8.7	11.0
.054	299.9	3.21	8.5	12.0
.086	300.3	3.43	. .	. .
1899.98	300.3	3.29	8.6	11.1

20. DM. −11°646.

$\alpha = 3^h\ 16^m\ 44^s$; $\delta = -11°\ 34'.7$

1900.051	226.9	0.33	8.5	8.8
.054	227.6	0.[illegible]8	8.8	8.8
1900.05	227.3	0.35	8.6	8.8

21. DM. −13°615.

$\alpha = 3^h\ 21^m\ 7^s$; $\delta = -13°\ 25'.2$

1900.086	12.0	1.33	8.5	9.5
.119	10.4	1.49	8.5	9.5
.128	12.8	1.57	8.5	9.0
1900.11	11.1	1.46	8.5	9.3

22. DM. −12°680.

$\alpha = 3^h\ 33^m\ 9^s$; $\delta = -11°\ 52'.3$

	°	″	M	M
1900.070	88.5	0.64	8.5	9.0
.128	88.1	0.63	8.5	9.5
1900.10	88.3	0.64	8.5	9.2

23. DM. −13°724.

$\alpha = 3^h\ 39^m\ 1^s$; $\delta = -13°\ 36'.2$

1900.034	88.0	1.05	9.0	9.2
.051	86.0	1.10	9.0	9.2
.054	88.0	1.20	9.0	9.0
1900.05	87.3	1.12	9.0	9.1

24. DM. +11°543.

$\alpha = 3^h\ 52^m\ 5^s$; $\delta = +11°\ 12'.3$

1900.070	266.3	1.42	8:5	11.0
.119	263.6	1.47	8.5	11.5
1900.09	265.0	1.45	8.5	11.3

25. DM. +11°548.

$\alpha = 3^h\ 52^m\ 56^s$; $\delta = +11°\ 50'.1$

1900.070	327.8	0.80	8.5	9.0
.119	323.7	0.78	8.8	9.2
1900.09	325.7	0.79	8.6	9.1

26. D.M. −10°799.

$\alpha = 3^h\ 53^m\ 13^s$; $\delta = -10°\ 31'.0$

1900.031	257.8	2.18	9.0	9.5
.034	259.1	2.23	9.0	9.5
.051	258.1	2.35	9.0	9.2
1900.04	258.3	2.25	9.0	9.4

27. DM. +9°523.

$\alpha = 3^h\ 53^m\ 31^s$; $\delta = +9°\ 31'.0$

1898.830	209.5	0.54	8.0	8.5
1900.070	212.0	0.55	8.2	8.5
1899.45	210.8	0.55	8.1	8.5

28. DM. +11°552.

$\alpha = 3^h\ 54^m\ 8^s$; $\delta = +11°\ 10'.6$

1900.070	342.1	0.97	9.0	9.2

29. DM. −10°808.

$\alpha = 3^h\ 54^m\ 51^s$; $\delta = -10°\ 36'.2$

1900.031	308.6	0.43	8.5	8.8
.051	314.4	0.45	8.5	8.8
1900.04	311.5	0.44	8.5	8.8

30. DM. −23°1810.

$\alpha = 4^h\ 9^m\ 14^s$; $\delta = -23°\ 22'.7$

1900.051	177.3	5.30	6.5	13.5
.086	176.2	5.30	6.8	14.0
1900.07	176.7	5.30	6.6	13.7

31. DM. −10°1026.

$\alpha = 4^h\ 45^m\ 20^s$; $\delta = -9°\ 56'.7$

1900.067	333.2	1.05	8.5	9.0
.119	333.6	1.02	8.5	9.0
.128	334.6	1.09	8.5	9.0
1900.10	333.8	1.05	8.5	9.0

32. DM. −10°1026.

$\alpha = 4^h\ 48^m\ 51^s$; $\delta = -10°\ 40'.9$

	°	″	M	M
1900.067	249.0	1.08	9.0	9.2
.119	249.0	0.85	9.1	9.1
.128	247.6	1.01	9.0	9.0
1900.11	248.5	0.98	9.0	9.1

33. DM. +0°974.

$\alpha = 5^h\ 6^m\ 33^s$; $\delta = +0°\ 23'.7$

1898.707	322.7	0.14	7.5	8.0
.860	324.1	0.16	. .	. .
1899.711	325.8	0.17	. .	. .
1899.09	324.2	0.16	7.5	8.0

34. DM. −10°1125.

$\alpha = 5^h\ 8^m\ 38^s$; $\delta = -10°\ 44'.1$

1900.051	108.9	1.14	8.8	12.0
.054	110.1	0.95	9.0	13.0
1900.05	109.5	1.05	8.9	12.5

35. DM. −11°1118.

$\alpha = 5^h\ 11^m\ 40^s$; $\delta = -11°\ 5'.55$

1900.031	64.0	2.68	9.0	10.5
.034	65.1	2.79	9.0	10.5
.051	65.1	2.64	9.0	11.5
1900.05	64.7	2.70	9.0	10.8

36. DM. −11°1126.

$\alpha = 5^h\ 13^m\ 3^s$; $\delta = -11°\ 4'.9$

1900.034	186.0	0.70	9.0	11.0
.051	185.3	0.77	9.0	12.0
1900.04	185.6	0.73	9.0	11.5

37. DM. −12°1215.

$\alpha = 5^h\ 32^m\ 36^s$; $\delta = -12°\ 26'.6$

1900.086	10.5	0.78	9.0	11.5
.128	10.2	0.72	9.0	11.0
1900.10	10.4	0.75	9.0	11.3

38. DM. +22°1017.

$\alpha = 5^h\ 38^m\ 55^s$; $\delta = +22°\ 51'.8$

1899.933	145.9	0.55	8.8	9.0
1900.051	144.7	0.51	8.5	8.8
.054	145.9	0.47	8.5	8.5
1900.01	145.5	0.51	8.6	8.8

39. DM. +21°984.

$\alpha = 5^h\ 41^m\ 9^s$; $\delta = +21°\ 50'.3$

1900.051	39.7	0.28	8.5	8.8
.054	43.9	0.28	8.3	8.3
.070	46.0	0.34	8.5	8.5
1900.06	43.2	0.30	8.4	8.5

40. DM. +20°1135.

$\alpha = 5^h\ 45^m\ 12^s$; $\delta = +20°\ 6'.6$

1900.070	10.2	3.61	8.5	9.5

41. DM. −11°1524.

$\alpha = 6^h\ 28^m\ 12^s$; $\delta = -11°\ 59'.6$

	°	″	M	M
1900.031	194.5	1.59	8.5	12.0
.034	196.5	1.19	8.5	12.5
1900.03	195.5	1.54	8.5	12.2

42. DM. −12°1535.

$\alpha = 6^h\ 28^m\ 28^s$; $\delta = -13°\ 1'.0$

1900.031	176.9	3.72	9.1	12.0
.034	176.4	3.95	9.0	10.5
1900.03	176.7	3.83	9.0	11.5

43. DM. −12°1540.

$\alpha = 6^h\ 28^m\ 54^s$; $\delta = -12°\ 2'.3$

1900.031	314.0	1.12	8.3	8.8
.034	313.6	1.10	8.5	8.8
1900.03	313.8	1.11	8.4	8.8

44. DM. −11°1577.

$\alpha = 6^h\ 34^m\ 53^s$; $\delta = -11°\ 36'.7$

1900.031	145.7	2.20	8.5	12.5
.086	146.5	2.36	8.5	14.0
1900.06	146.1	2.28	8.5	13.2

45. DM. −12°1591.

$\alpha = 6^h\ 37^m\ 38^s$; $\delta = -12°\ 33'.1$

1900.034	176.6	0.50	9.0	9.5

46. DM. −12°1593.

$\alpha = 6^h\ 37^m\ 42^s$; $\delta = -12°\ 12'.3$

1900.034	151.5	2.52	9.1	9.8
.128	155.3	2.42	9.1	10.5
1900.08	153.4	2.47	9.1	10.2

47. DM. −13°1789.

$\alpha = 6^h\ 59^m\ 4^s$; $\delta = -13°\ 32'.8$

1900.086	307.3	1.51	9.1	13.0

48. DM. −12°1781.

$\alpha = 7^h\ 1^m\ 29^s$; $\delta = -12°\ 47'.7$

1900.086	150.5	2.67	8.5	8.8
.128	149.8	2.67	8.5	8.5
1900.10	150.2	2.67	8.5	8.7

49. DM. −12°1962.

$\alpha = 7^h\ 21^m\ 16^s$; $\delta = -12°\ 6'.1$

1900.051	203.0	0.50	9.0	10.5

50. DM. −12°1979.

$\alpha = 7^h\ 22^m\ 53^s$; $\delta = -12°\ 12'.8$

1900.051	93.4	0.57	8.5	9.0
.128	95.4	0.45	8.5	9.5
1900.09	94.4	0.51	8.5	9.2

51. DM. −11°2086.

$\alpha = 7^h\ 39^m\ 52^s$; $\delta = -12°\ 4'.4$

1900.031	47.0	0.90	8.8	9.0
.034	45.1	0.82	8.7	9.5
.051	46.2	0.88	8.6	9.0
1900.04	46.1	0.87	8.7	9.2

52. DM. −11°2105.

$\alpha = 7^h\,43^m\,15^s$; $\delta = -11°\,43'.7$

	°	″	M	M
1900.031	90.3	3.22	9.2	13.5

53. DM. −11°2133.

$\alpha = 7^h\,47^m\,38^s$; $\delta = -11°\,24'.1$

1900.031	9.6	0.34	8.5	8.5

54. DM. −12°2204.

$\alpha = 7^h\,49^m\,55^s$; $\delta = -12°\,34'.0$

1900.031	10.4	1.64	8.5	8.8
.034	9.0	1.69	8.5	8.8
.051	8.7	1.70	8.5	8.7
1900.04	9.4	1.68	8.5	8.8

55. DM. −10°2832.

$\alpha = 9^h\,19^m\,10^s$; $\delta = -10°\,39'.5$

1900.031	108.2	0.61	8.5	9.0

56. DM. −12°2891.

$\alpha = 9^h\,21^m\,26^s$; $\delta = -13°\,3'.8$

1900.031	156.6	1.64	8.5	9.5

57. ———.

$\alpha = 14^h\,28^m\,59^s$; $\delta = +49°\,37'.5$

1898.346	138.5	1.26	11.5	12.0
.353	138.4	1.28	. .	. .
1898.35	138.5	1.27	11.5	12.0

This is the companion of *OΣ* 283.

58. DM. 10°4639.

$\alpha = 18^h\,10^m\,28^s$; $\delta = -10°\,7'.4$

1899.568	128.1	0.84	9.0	9.5
.571	124.4	0.63	8.0	8.5
.611	124.9	0.75	9.0	9.5
1899.58	125.8	0.74	8.9	9.2

59. DM. −13°4916.

$\alpha = 18^h\,12^m\,26^s$; $\delta = -13°\,11'.9$

1899.568	340.4	0.76	8.5	8.8
.571	338.0	0.63	8.5	9.0
.611	338.6	0.59	8.8	9.0
1899.58	339.0	0.66	8.6	8.9

60. DM. −11°4590.

$\alpha = 18^h\,13^m\,19^s$; $\delta = -11°\,2'.9$

1899.571	240.4	1.00	8.8	13.0
.611	238.7	1.03	8.6	11.5
.722	239.6	0.95	. .	. .
1899.64	239.6	0.99	8.7	12.2

61. DM. −14°4997.

$\alpha = 18^h\,13^m\,53^s$; $\delta = -14°\,49'.5$

1899.583	116.8	2.29	9.0	10.0
.611	116.5	2.37	8.8	9.5
.648	116.4	2.44	9.0	10.5
.651	117.1	2.40	9.0	10.0
1899.62	116.7	2.38	9.0	10.0

62. DM. −11°4605.

$\alpha = 18^h\,16^m\,13^s$; $\delta = -11°\,41'.2$

	°	″	M	M
1899.550	213.9	0.39	9.0	9.2
.553	211.3	0.39	. .	. .
.571	212.6	0.42	9.0	9.5
1899.56	212.6	0.40	9.0	9.4

63. DM. −12°5031.

$\alpha = 18^h\,18^m\,35^s$; $\delta = -12°\,15'.4$

1899.550	316.4	3.00	8.8	12.5
.553	316.9	3.04	. .	. .
.571	314.9	2.91	8.3	12.5
1899.56	316.1	2.98	8.5	12.5

64. DM. −16°4864.

$\alpha = 18^h\,19^m\,35^s$; $\delta = -16°\,33'.8$

1899.648	12.1	1.04	9.0	10.0

65. DM. +84°409.

$\alpha = 18^h\,19^m\,53^s$; $\delta = +84°\,34'.5$

1898.565	269.3	1.49	9.5	10.0
.595	267.4	1.55	9.0	10.0
.598	267.4	1.44	9.0	10.0
1898.59	268.0	1.49	9.2	10.0

There is also a 12th magnitude companion in 24°.5 : 9″.10.

66. ———.

$\alpha = 18^h\,22^m\,42^s$; $\delta = +48°\,42'.2$

	°	″
1898.572	309.9	0.33
.592	307.6	0.36
.595	312.9	0.32
.707	309.6	0.36
1899.686	308.2	0.31
1898.82	309.6	0.34

This is the south component of *OΣ* 351. The *OΣ* pair is a close one, its distance being about 0″.6. Its components have shown no certain motion. At the time of the discovery of the new component, Professor BURNHAM stated, in a private letter, that he could recall no other instance of three stars so close together. I have since found another case in number 91 of this list, which is still closer and more difficult.

67. DM. −15°1982.

$\alpha = 18^h\,23^m\,34^s$; $\delta = -15°\,7'.7$

1899.648	323.5	1.73	8.8	12.0

68. DM. −12°5071.

$\alpha = 18^h\,24^m\,18^s$; $\delta = -12°\,19'.2$

1899.550	121.3	3.24	9.0	12.0
.553	120.4	3.00	8.8	11.0
.571	119.7	2.93	8.8	10.0
1899.56	120.5	3.06	8.9	11.0

69. DM. −13°5003.

$\alpha = 18^h\,24^m\,21^s$; $\delta = -13°\,0'.8$

1899.571	246.6	0.31	8.0	8.0
.611	245.1	0.31	. .	. .
.722	246.0	0.33	. .	. .
1899.63	245.9	0.32	8.0	8.0

70. DM. −11°4692.

$\alpha = 18^h\,32^m\,16^s$; $\delta = -11°\,26'.7$

	°	″	M	M
1899.571	216.4	0.87	8.5	9.0
.611	215.5	0.96	8.8	9.2
.722	217.3	0.79	. .	. .
1899.63	216.4	0.87	8.6	9.1

71. DM. −10°4914.

$\alpha = 18^h\,55^m\,43^s$; $\delta = -10°\,17'.7$

1899.611	353.0	0.82	9.2	9.5
.756	354.9	0.53	. .	. .
.759	352.7	0.55	. .	. .
1899.71	353.5	0.63	9.2	9.5

72. DM. −10°5035.

$\alpha = 19^h\,14^m\,53^s$; $\delta = -10°\,44'.5$

1899.611	61.9	1.12	7.3	12.5

73. DM. −10°5058.

$\alpha = 19^h\,17^m\,45^s$; $\delta = -10°\,11'.4$

1899.611	223.1	1.11	9.0	10.0
.635	220.0	1.05	9.1	10.5
.756	225.7	1.06	9.0	10.0
.759	224.2	0.88	9.0	10.0
1899.69	223.3	1.03	9.0	10.2

74. DM. −12°5390.

$\alpha = 19^h\,19^m\,18^s$; $\delta = -12°\,2'.2$

1899.611	85.8	1.64	8.0	12.0
.759	86.8	1.50	. .	. .
1899.68	86.3	1.57	8.0	12.0

75. DM. −12°5417.

$\alpha = 19^h\,24^m\,2^s$; $\delta = -12°\,51'.3$

1899.609	201.6	0.49	7.5	8.0
.611	200.9	0.52	7.5	8.0
.759	204.4	0.47	7.5	8.0
1899.66	202.3	0.49	7.5	8.0

76. DM. −11°5114.

$\alpha = 19^h\,40^m\,28^s$; $\delta = -11°\,5'.1$

1899.600	262.1	0.71	9.0	10.5

77. DM. −11°5147.

$\alpha = 19^h\,45^m\,5^s$; $\delta = -11°\,2'.7$

1899.600	317.0	0.46	9.0	11.5

78. DM. −13°5553.

$\alpha = 19^h\,56^m\,36^s$; $\delta = -12°\,54'.2$

1899.759	181.7	2.18	8.5	8.8

79. DM. −12°5621.

$\alpha = 19^h\,56^m\,45^s$; $\delta = -12°\,14'.1$

1899.759	243.5	0.60	8.5	8.8

80. DM. −19°5724.

$\alpha = 20^h\,3^m\,30^s$; $\delta = -19°\,42'.2$

1899.651	1.5	2.57	8.5	10.2

81. DM. −12°5865.

$\alpha = 20^h\ 50^m\ 3^s$; $\delta = -12°\ 10'.3$

	°	″	M	M
1899.571	4.8	0.35	8.5	8.8
.574	4.9	0.32	8.5	8.8
.821	6.3	0.30	8.7	9.0
1899.65	5.3	0.32	8.6	8.9

82. DM. −13°5803.

$\alpha = 20^h\ 52^m\ 36^s$; $\delta = -13°\ 0'.4$

1899.571	12.8	2.63	8.5	9.0
.574	13.5	2.68	8.5	9.0
.635	12.7	2.54	8.5	8.8
1899.59	13.0	2.62	8.5	8.9

83. DM. −13°5810.

$\alpha = 20^h\ 53^m\ 35^s$; $\delta = -13°\ 35'.9$

1899.571	75.9	0.20	8.5	8.5
.574	79.0	0.20	8.5	8.8
.635	75.8	0.23	8.5	8.8
1899.59	76.9	0.21	8.5	8.7

84. DM. −12°5911.

$\alpha = 21^h\ 2^m\ 25^s$; $\delta = -12°\ 35'.5$

1899.574	327.9	4.45	9.0	14.0
.670	326.7	4.56	9.0	14.5
1899.62	327.3	4.50	9.0	14.2

85. CDM. −29°17611.

$\alpha = 21^h\ 5^m\ 5^s$; $\delta = -29°\ 22'.1$

1899.611	143.8	3.06	8.8	11.0
.648	147.1	2.80	8.8	12.5
.651	142.7	2.76	8.5	12.0
1899.64	144.5	2.87	8.6	11.8

86. DM. −11°5574.

$\alpha = 21^h\ 14^m\ 51^s$: $\delta = -11°\ 13'.6$

1899.648	238.3	4.41	8.7	12.2
.651	237.6	4.31	8.5	11.5
.821	238.6	4.46	8.5	13.0
1899.71	238.2	4.39	8.6	12.2

87. DM. −12°6041.

$\alpha = 21^h\ 31^m\ 34^s$; $\delta = -11°\ 51'.6$

1899.821	232.6	3.97	9.0	14.0

88. DM. −13°5982.

$\alpha = 21^h\ 33^m\ 42^s$; $\delta = -12°\ 48'.4$

	°	″	M	M
1899.574	226.6	1.30	9.2	12.0
.648	225.5	1.41	9.2	11.5
.651	222.5	1.22	9.2	12.5
1899.62	224.9	1.32	9.2	12.0

89. DM. −12°6113.

$\alpha = 21^h\ 46^m\ 7^s$; $\delta = -12°\ 7'.1$

1899.635	10.0	0.63	9.1	9.3
.648	9.3	0.62	9.1	9.5
.651	6.4	0.58	9.1	9.1
1899.64	8.6	0.61	9.1	9.3

90. DM. −11°5889.

$\alpha = 22^h\ 33^m\ 47^s$; $\delta = -11°\ 30'.9$

1899.651	219.2	1.94	9.2	11.5
.821	219.7	2.04	9.0	12.5
.933	221.6	2.02	9.1	13.0
1899.80	220.2	2.00	9.1	12.3

91. ———.

$\alpha = 22^h\ 38^m\ 45^s$; $\delta = +46°\ 38'.7$

1898.630	227.7	0.15	8.0	10.0
.690	229.5	0.17	. .	. .
.707	224.4	0.13	. .	. .
1898.67	227.2	0.15	8.0	10.0

This is the north component of OΣ 476. For the OΣ pair, I obtain

1898.64 327°.8 0″.54 3n

Cf. note to number 66 of this list.

92. ———.

$\alpha = 22^h\ 40^m\ 7^s$; $\delta = +67°\ 12'.5$

1898.674	354.5	0.96	. .	. .
.860	350.3	1.12	. .	. .
1898.77	352.4	1.04	. .	. .

This is the companion of *h* 1807.

93. DM. −13°6289.

$\alpha = 22^h\ 46^m\ 46^s$; $\delta = -13°\ 28'.6$

1899.651	146.1	4.42	9.0	11.0
.821	145.6	4.66	9.0	10.0
.933	146.6	4.52	9.0	11.0
1899.80	146.1	4.53	9.0	10.7

94. DM. −10°6064.

$\alpha = 23^h\ 2^m\ 30^s$; $\delta = -10°\ 12'.5$

	°	″	M	M
1899.611	246.8	4.58	8.6	13.0
.635	246.3	4.43	8.5	12.5
.722	246.9	4.45	8.3	13.0
1899.66	246.7	4.49	8.5	12.8

95. DM. −13°6390.

$\alpha = 23^h\ 16^m\ 37^s$: $\delta = -12°\ 49'.2$

1899.711	222.3	0.58	9.2	10.5
.722	219.3	0.48	9.2	10.5
.756	221.6	0.48	. .	. .
1899.73	221.1	0.51	9.2	10.5

96. DM. −11°6141.

$\alpha = 23^h\ 43^m\ 5^s$; $\delta = -10°\ 50'.7$

1899.722	105.8	1.19	9.2	10.5
.759	102.9	1.00	. .	. .
.821	103.3	1.12	9.2	10.0
1899.77	104.0	1.10	9.2	10.2

97. DM. −11°6150.

$\alpha = 23^h\ 46^m\ 54^s$: $\delta = -11°\ 7'.4$

1899.722	40.0	1.11	9.1	9.8
.759	39.0	1.06	. .	. .
.821	38.4	1.09	9.0	9.8
1899.77	39.1	1.07	9.0	9.8

98. DM. −13°6490.

$\alpha = 23^h\ 51^m\ 58^s$: $\delta = -13°\ 31'.1$

1899.648	120.8	1.55	8.5	10.0
.722	123.1	1.70	8.5	10.5
.821	120.8	1.57	8.2	9.5
1899.73	121.6	1.61	8.4	10.0

99. DM. −13°6496.

$\alpha = 23^h\ 53^m\ 46^s$: $\delta = -13°\ 20'.4$

1899.648	361.4	3.42	8.6	12.2
.722	359.7	3.57	8.8	13.0
.821	362.9	3.37	8.8	11.5
1899.73	361.1	3.45	8.7	12.3

100. DM. −10°6223.

$\alpha = 23^h\ 59^m\ 40^s$; $\delta = -10°\ 25'.4$

1899.648	349.5	4.31	9.2	9.5
.722	349.3	4.31	9.2	9.8
.821	350.0	4.35	9.2	9.5
1899.73	349.6	4.32	9.2	9.6

ERRATA. — The position-angles of my observations of *ι Coronae Borealis*, given in *Astr. Jour.*, No. 427, should all be increased 100°. In the same paper, *For* Σ 2026, *read* Σ 2032.

Lick Observatory, Mt. Hamilton, California. 1900 *February* 19.

CONTENTS.

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TO THE TWENTIETH VOLUME.

C.

D.

E.

Plate for Volume XX (opposite page 190).